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**Canadian Chemical Research
Applied to Agriculture
and Forest Products**

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THE SOCIETY OF CHEMICAL INDUSTRY**

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PREFACE

At meetings of the Canadian Section of the Society of Chemical Industry held during the Session in Toronto, Ottawa and Montreal, a number of papers have been read and contributions presented which the Publication Committee have collected and feel is most desirable should be issued in pamphlet form for the benefit of members and for the use of those who are interested in Chemical Industry in Canada.

The meetings of the Society were held as follows:

1917

28th September, Ottawa—"Standzrd Method of Water Analysis."

By Dr. A. M. McGill and Mr. J. Race, F.I.C.

19th October, Toronto—"Milk Powder."

By Mr. S. B. Trainer.

"Standardization of deci-normal Sulphuric Acid."

By Dr. Tingle and Mr. Babington.

2nd November, Montreal—"The Story of Sulphuric Acid"—Illustrated.

By Mr. H. V. Smythe.

16th November, Toronto—"Soil Moisture and Drainage."

By Prof. W. H. Day, B.A.

13th December, Ottawa—"Industrial Research."

Dr. R. F. Ruttan.

14th December, Montreal—"Utilization of our Peat Resources."

By Mr. F. B. Haanel.

1918—

18th January, Tofoanto—"Petroleum: Its History and Development."

By Mr. W. A. P. Schorman, B.A. Sc.

25th January, Montreal—(a) "Estimation of Cellulose in Wood."

By Mr. Hovey.

(b) "Waste Sulphite Liquors."

By Mr. Bryant.

31st January, Ottawa—"Fuel Problem from the Chemist's View-point."

By E. Stansfield, M.Sc.

22nd February, Toronto—"Chemical Research in Agriculture."

By Dr. M. C. Boswell.

21st March, Toronto—"Soil Surveys in Ontario."

By Prof. R. Harcourt.

21st March, Ottawa—"High Explosives."

I. Grageroff.

19th April, Montreal—"Coal Gas Manufacture."—Illustrated.

By Mr. F. F. Kennedy.

10th May, Montreal—(a) "Industrial Reconstruction."

By Mr. Wardleworth.

(b) "Organization for Chemists."

By Dr. Bates.

23rd May, Ottawa—Annual Meeting.

(a) "Standard Method for Estimating Moisture in Wheat."

By Dr. J. T. Birchard.

(b) "Examination of Commercial Dextrines."

Messrs. Babington, Tingle and Watson.

(c) "Industrial Manufacture of Ethyl Alcohol from Wood Waste."

By Mr. Tomlinson.

The present publication embraces papers selected from those delivered at these meetings, written by well known chemists in such a manner as to be readily followed by those who may not be familiar with the science of chemistry.

The Society of Chemical Industry was founded in 1881 in England and has reached out till it now comprises members in all parts of the world. The wide distribution of its members rendered it necessary to devise means of holding meetings in places which would be accessible to its members. This brought about the formation of Sections of the Society in various centres and countries and lead to the formation of a Canadian Section.

This affords members in Canada an opportunity for the discussion and interchange of ideas on all matters appertaining to industries in which chemistry plays a part, and the bringing together of the manufacturer, the engineer and the chemist, and recently a form of associate membership has been instituted for those desirous of attending the meetings of the Society, but not including subscription to the Journal of the Society, which is published fortnightly in London, and is the most important periodical on applied chemistry and chemical engineering in the world, being widely recognized as an invaluable aid to all those whose occupation demands some chemical knowledge. It contains reports *in extenso* or in abstract form of the papers read before general and sectional meetings, with discussions thereupon; also abstracts of all British, Continental and United States patents on chemical and chemical engineering subjects; classified lists of British applications for patents and "Complete Specifications Accepted;" abstracts of articles relating to applied chemistry selected from British and foreign technical journals and transactions of learned societies; and a classified **Trade Report**, giving information on the Board of Trade returns, statistics, alterations in tariffs, Customs regulations, laws affecting chemical industries, consular reports, new openings for trade and new books. The following divisions, under which the abstracts are arranged, serve to show what industries are represented in the Society:

- | | |
|---|---|
| 1. General Plant; Machinery. | 12. Fats; Oils; Waxes. |
| 2a. Fuel; Gas; Mineral Oils and Waxes. | 13. Paints; Pigments; Varnishes; Resins. |
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| 7. Acids; Alkalies; Salts; Non-metallic Elements. | 19a. Foods. |
| 8. Glass; Ceramics. | 19b. Water Purification; Sanitation. |
| 9. Building Materials. | 20. Organic Products; Medicinal Substances; Essential Oils. |
| 10. Metals; Metallurgy, including Electro-metallurgy. | 21. Photographic Materials and Processes. |
| 11. Electro-Chemistry. | 22. Explosives; Matches. |
| | 23. Analysis. |
| | 24. Miscellaneous Abstracts. |

The Canadian Section extends to all who may be interested an invitation to be present at its meetings, the dates of which may be obtained from the Secretary.

The Chairman and the members of the Canadian Section wish to express their indebtedness to the Ontario Government for a grant toward the expense of publishing this work.

Toronto, March 1919.

CHEMISTRY AND AGRICULTURE

AN ADDRESS TO THE SOCIETY OF CHEMICAL INDUSTRY, FEB. 22ND, 1918

BY DR. MAITLAND C. BOSWELL.

IT is obvious to anyone at all in touch with any aspect of the relation of Chemistry to agriculture that a comprehensive treatment of this subject is quite impossible in the short time which I have at my disposal this evening. The mere description of the groups into which the subject has been divided by the investigator, would alone occupy my entire time. It is evident that I must restrict myself to the consideration of certain aspects of Chemistry and agriculture. A choice must be made of the immense mass of facts and data which has slowly accumulated since man first began to use the experimental method in place of pure speculation in the investigation of plant growth. It is unnecessary, I take it, to speak to this audience of chemists, of the applications of Analytical Chemistry, important as they have been, to the quantitative analysis of soils and fertilizers, or to the proximate analysis of foodstuffs. With these and allied groups you are perfectly familiar. Rather would I attempt to trace from early times the development of the general ideas regarding the mechanism of plant growth,* the generalizations, if any, which investigators have been able to make from the mass of observed facts, and the bearing these have had on practical agriculture, with the idea of learning (1) the present status of Chemistry with regard to agriculture—what specific outstanding facts Chemistry has really given us with respect to plant growth, (2) why, in view of the advanced condition of the pure and industrial Chemistry of today, it has not given us more information than it has, (3) how we can remedy this defect, increase our knowledge, and travel more surely and speedily toward the desired ultimate goals—the complete understanding of the mechanism of plant growth (as far as it is a physico chemical mechanism) and the elevation of agriculture from the rank of an empirical art to that of a more definite science, and (4) to examine the economic and other conditions which prevail at the present time in order to determine whether the information of which we are now actually in possession can be effectually used or not, for the purposes of increased production of foodstuffs.

Let me first, then, in the briefest manner, trace the advance of our knowledge with respect to the chemical changes which bear upon plant growth—the chemical changes in the soil, in the gases which surround the plant, and within the plant itself. This work was at the outset not attacked according to any systematic plan, or by the deductive method through the aid of any working hypothesis regarding the mechanism of plant growth, but by the spasmodic accumulation of isolated facts by curious observers. Evidences of these are to be found in the earliest written records, and a quite extensive literature on agriculture grew up in Roman times. Much of this consists of speculations, many of them very ingenious, to account for plant growth and to fix the factors on which it is dependent. This speculative method of solving the problems of plant growth continued through mediæval times up to the inauguration of the experimental method by Bacon and others. During this historical period of over 15 centuries there naturally was accumulated a vast collection of unconnected empirical observations. Much of this was useful information which worked itself by slow degrees into practical agriculture. To such belong the observations of the value of stable manure, of the ash of plants as manure, of liming, of cultivation, and the advantages of the bare fallow. When it is recalled that oxygen had yet to be identified as an element, and that even

*For the early history of agriculture and plant physiology I have drawn on the standard treatises by Jost, Pfeffer and Russell.

he phlogiston theory of combustion had still to be enunciated, run its course, and be rejected, it is unnecessary to state that the information had no scientific basis whatever, and that attempts to establish relationships of cause and effect were almost entirely flights of the fancy. The experimental method had not yet been introduced. However, it would be a very great mistake to belittle or underestimate this early work. Much of the subsequent work of agricultural chemistry consisted in the classification and correlation and, as far as possible, the establishment of causal relationships among these numerous observations. Thus the early tillers of the soil many centuries before the commencement of the Christian era found out those outstanding practical facts which have ever since formed the basis of practical agriculture; the naive philosophers of Roman and mediæval times attempted speculatively to explain those facts; but it remained for modern Chemistry with the experimental method and the laboratory devices of quantitative science to connect these isolated facts together and furnish a basis for the more rapid and more rational investigation of all the phenomena of plant growth, and thus to attempt the building up of a rational agriculture.

No useful purpose would be served in tracing this early work of collecting the rules of practical agriculture, or describing the explanations, ingenious and otherwise, which were advanced by speculators to account for them. Chemistry had practically nothing to do with either. Indeed Chemistry as a science did not exist. It was still merely the mysterious instrument of the apothecary, medicine man and alchemist.

What may be considered the first period of chemical investigation on plant growth commenced about 1630 and extended to about 1750 and may be said to be distinguished by the search for the principle of vegetation. Van Helmont believed water to be this principle. His now celebrated Brussels experiment was performed early in the seventeenth century. Van Helmont describes it in these words: "I took an earthen vessel in which I put 200 lbs. of soil dried in an oven, then I moistened with rain water and pressed hard into it a shoot of willow weighing 5 lbs. After exactly 5 years the tree that had grown up weighed 169 lbs. and about 3 oz. The vessel had never received anything but rain water or distilled water to moisten the soil when this was necessary, and it remained full of soil which was still tightly packed, and, lest any dust from outside should get into the soil, it was covered with a sheet of iron coated with tin but perforated with many holes. I did not take the weights of the leaves that fell in the autumn. In the end I dried the soil once more and got the same 200 lbs. that I started with, less about 2 oz. Therefore the 169 lbs. of wood, bark and root arose from the water alone." The experiment convinced Van Helmont that he had witnessed a transmutation of water into the compounds of the plant. Boyle, who repeated the experiment with squash, obtained similar results and was satisfied with Van Helmont's explanation. However, according to modern plant physiology, the conclusion is completely wrong, for the reason that Van Helmont and Boyle ignored two factors, the part played by the air and the part played by the missing 2 oz. of soil. Plant physiologists today believe that the carbon of the plant comes exclusively from the carbon dioxide of the air while the inorganic constituents, the ash of the plants, is obtained by the plants from the soil, and that a complex set of reactions between the plant and the soil and the plant and the atmosphere gives rise to the phenomenon of growth involving no transmutations whatever. However, an uncertainty still remained as to whether plants get their ash from the soil or synthesize it by some process of transmutation, and as late as 1842 the University of Gottingen offered a prize for the solution of the problem. Weigmann and Polstorff won the prize by a dissertation describing experiments which the scientific world has accepted as proving conclusively that every trace of ash present in the plant comes either from the original seed or the soil surrounding the roots. In their first series of experiments plants were grown upon sand from which soluble materials had been extracted with acids. One set of plants was given distilled water only, the other set was given a mixture of the inorganic salts usually found in plants.

It was observed (1) that the plants treated with distilled water alone did not develop much beyond the seedling stage, thus proving the necessity of inorganic salts for growth; (2) the ash of the plants grown on sand with distilled water alone weighed slightly more than the ash present in the same weight of seed. Thinking that this might have come from the sand Weigmann and Polstorff repeated the experiment using platinum scraps in place of extracted sand and found the ash exactly equal to the ash of the same weight of seeds.

Viewing the experiments of Van Helmont and Boyle in the light of modern Chemistry they are apt to provoke a smile. However, this work should not be lightly dismissed. There is no field of science in which Nature sets such subtle traps as in plant and animal physiology. The mistake of Van Helmont and Boyle is typical of the kind of errors which have commonly been made in these sciences. In no science is it so easy to overlook a factor vital to the whole experiment and draw utterly worthless conclusions from perfectly good experiments. And it seems to me that many of Van Helmont's scornful critics should walk very warily and be very careful that they have not themselves fallen into another of Dame Nature's traps not very different from the one that appears to have caught their more able predecessors, Van Helmont and Boyle. The work of plant physiologists has not until quite recently been characterized by what a chemist or physicist would consider careful regard to exact conditions and precise analytical methods. To digress a little it seems to me that there is a great field for research in plant physiology for the chemist who is specially capable in (1) devising means of getting round the peculiar mechanical difficulties connected with quantitative experiments in plant physiology and (2) in working out modifications of the known analytical methods to fit the cases and give exact quantitative data. The difficulties in these two respects are very great. One does not work very long in research in plant physiology or examine very far into the literature of the subject to be very strongly impressed with these difficulties.

Following Van Helmont and Boyle in the search for the principle of vegetation came Glauber who about 1650 set up the hypothesis that saltpetre is that principle. He extracted saltpetre from the earth cleaned out of cattlesheds, and rightly supposed that it resulted from the chemical changes in the excreta of animals housed there. Upon applying the saltpetre to soil he obtained enormous increases of crops. He put the two facts together and drew the sweeping conclusion that he had found the principle of vegetation to be saltpetre. This belief was shared by many later writers.

However, in 1761 Kulbel believed from his work that the decomposed organic matter of the soil called humus is the long sought principle.

In 1727 Boerhaave taught that the plant absorbs juices from the soil consisting of matter from the animal, vegetable and mineral kingdoms which the plant is able to work up into what may be considered the chyle of the plant and that this is the principle of vegetation. This is seen to be a distinct advance over the ideas of the predecessors of Boerhaave, for we seem to see here the idea that the growth is due not to a single substance or principle, but to a combination of substances of different origins which the plant is capable of working up into a special body endowed with all the functions of growth. Thus we have the germ of the idea of the cell with its protoplasm.

The next period extending from 1750 to 1800 may be called a search for plant nutrients. Francis Horne gave a decided impetus to this search. By his pot experiments which he described in a book in 1756 called "The Principles of Agriculture and Vegetation" at the suggestion of the Edinburgh Society for the Improvement of Arts and Manufactures, Horne showed the effect of various substances upon plant growth. He found that very different compounds as saltpetre (now called potassium nitrate), Epsom salt (now magnesium sulphate), vitriolated tartar (now potassium sulphate), olive oil and many others lead to increased growth. He concludes that plant growth depends upon several factors and names the following as belonging to these—air, water,

earth, salts of various kinds, oil and heat. Horne's work was an advance, not only because of the facts he actually observed, and recorded, but because he indicated two methods of attacking plant problems—pot experiments and plant analysis. As work progressed other plant nutrients were discovered. Thus the value of lime and humus the physical effect of sand in making the soil more open and accessible to air, and the value of phosphates was observed.

In 1771 Priestley made his celebrated experiment of removing the product of respiration (which we now call carbon dioxide) from air and replacing it by dephlogisticated air (which we now call oxygen) by means of the leaves of plants. Thus Priestley showed, in the language of modern Chemistry, that carbon dioxide, a product of combustion and respiration is transformed by the plant leaves into oxygen. A year later in 1772 Priestley and Scheele independently discovered oxygen, prepared it in pure condition and studied its properties. And yet their minds were so prejudiced by the old phlogiston theory that they could not see that they had rendered this theory utterly untenable by their discovery. And Priestley actually died without perceiving the real nature of combustion, and still clinging tenaciously to his belief in phlogiston. So much is prejudice stronger than reason. There were the facts of combustion staring Priestley in the face and yet so powerful was the force of the accepted interpretation of the time, that even Priestley could not overcome it in his own mind. It is such extraordinary instances of the stultifying influence of an habitual mode of thought, sanctified as it were by long acceptance and usage which makes one pause and wonder whether today generalizations might not be made from the mass of data at our disposal, if our minds were not bound to the narrow channels of thought formed by the theories by which we have grown accustomed to interpret the facts of Physics and Chemistry.

It remained for Lavoisier to clear up the difficulties which stood in the way of a clear conception of combustion and to show the part which oxygen plays in it and once for all relegate phlogiston to the limbo of fantastic dreams. This enabled Ingen-housz and Senebier to give the interpretation of what later became known as the assimilation of carbon process—the transformation of the carbon dioxide of the air in the plant cell into carbon compounds, with the evolution of oxygen.

The period from the year 1800 may be called the modern period. This is characterized by more exact quantitative measurements which were made possible by the discovery of oxygen and the introduction by Lavoisier of the exact measurement of mass in chemical change, with all that this implied for the development of analytical methods. thus about 1804 De Sausseure studied the gas changes about plants in closed systems with various mixtures of air and carbon dioxide and followed the changes by gas analytical methods. He was thus able to establish the existence of the respiration process in plants—the breathing in of oxygen and the respiration of carbon dioxide at all times—and superposed upon this in sunlight the reverse process—the decomposition of carbon dioxide and the evolution of oxygen. He showed further that if carbon dioxide is entirely absent from the air reaching the plant it perished, also that water is decomposed and its constituents fixed by the plant, also that the soil furnishes but very small portion of the food of the plant but that this small portion consisting of compounds of nitrogen (which element he showed was not absorbed from the air by the plants with which he experimented), and inorganic materials, which he determined in the ash of the plant, are extremely important. He was particularly impressed with the value of phosphates and the alkali metals in accelerating plant growth. The work of De Sausseure is of a distinctly superior order. Here we find careful experiments with logical reasoning and correct conclusions.

It was about the same time 1802-1812 that Davy wrote his textbook on agricultural chemistry, giving the accepted knowledge of the time. He rejected, however, without experiment, De Sausseure's belief, founded on experiment, that the chief source of the carbon of the plant is the carbon dioxide of the air, and he expressed the opinion, without

any experimental proof whatever, that the humus of the soil constitutes the chief source. These and other opinions were unfortunate and through the high reputation of Davy were accepted, and retarded the growth of the science for some years. His emphasis of the importance of the physical properties of soils with relation to soil moisture and temperature, was important and laid the foundation of what has developed today into the department of soil physics.

Up to this time experiments had been confined to either the laboratory or to small pots. However, about 1834 Boussingault commenced field experiments on his farm at Bechelbronn in Alsace. He followed the quantitative methods of De Sausseure—used definite quantities of manures of determined composition and analysed the crops obtained. He determined the composition of crops at different stages of growth and the effect of manures upon their nitrogen and ash content.

A great deal of work was being done by other investigators but no conclusions of note were arrived at and no very great interest taken in plant growth.

This continued till 1840 when Liebig in his famous report to the British Association aroused the scientific world by bitter attacks on plant physiologists for their inaccurate and untrustworthy experiments and their failure to familiarize themselves with the accurate work of chemists, and censuring them particularly for clinging to what he considered the antiquated theory of humus as the source of the carbon of the plant. Liebig's invective and scorn laid the humus theory low, although it must in fairness be said, that no evidence has to this day been experimentally obtained to preclude the possibility that part of the plant carbon comes from the soil humus. Liebig's experiments which he published in his famous textbook "Chemistry and Its Application to Agriculture and Physiology" led him to the following conclusions: (1) Hydrogen and oxygen of the plant come from water. (2) Nitrogen comes from soil ammonia. (3) Certain mineral substances are essential as the alkali metals, phosphates for seed formation, and silicates for grasses and the straw of grains. (4) The composition of the ash indicates the needs of the plant, the mere presence in the plant being sufficient to indicate its essential character. (5) The good effect of lime and of cultivation is due to these facilitating the weathering of soil particles which is necessary in order to make the alkalies available. (6) In order to keep a soil fertile all that is necessary is to return to the soil the nitrogen and the mineral constituents which the crop has removed. Liebig expanded this idea still further, and stated his belief that when sufficient crop and soil analysis have been made, it would be possible to draw up tables by which a farmer, from a soil analysis, could be told exactly what mineral constituents he must add to make his soil suitable for any given crop. And patent manures were even made up and placed on the market. The production of crops had at last apparently been reduced to a mere matter of soil analysis by a chemist. Dame Nature had at last been cornered by a German chemist and ordered to throw up her hands and surrender. Liebig should have waited long enough to actually witness the act of surrender on the part of the wily and elusive old dame. Instead he seems to have fallen into the German error of supposing that having placed her in what appeared to be a very embarrassing position from which there was no apparent path of escape, she must of necessity surrender. At any rate he wrote all about the surrender in a book which passed through several editions in a short time. Here he insisted on the ability of the chemist to solve entirely the question of soil fertility by quantitative analysis. The determination of the constituents, particularly the alkali metals and phosphorus content of soil, would determine the soil deficiencies which could then be supplied by the proper application of Liebig's patent manure. It sounds like the prospectus literature of a modern oil company. Unfortunately for Liebig's mineral theory Mr. Lawes, afterwards Sir John Lawes, had just commenced his agricultural experiments at what was destined to be the most celebrated experimental farm in the whole world—the Rothamsted farm. Lawes, judging from his own experience, felt that many of Liebig's contentions were not

true. He fastened on to one, namely, Liebig's statement, that as turnips contain very little phosphorus, indeed a much smaller proportion than most plants or roots, they hence require very little phosphorus in the soil for their proper development. Lawes proved this statement to be entirely erroneous and notwithstanding the fact that the phosphorus content of turnips is low, they require for proper development just as much phosphorus in the soil as any other plant. Lawes did not stop here to attempt any interpretation of the fact but proceeded to follow it up by a series of blows which shook the mineral theory of Liebig to its foundation. Moreover, Liebig's patent manure proved a failure. In many cases it failed to manure. Thus Liebig found not only that Dame Nature had failed to surrender but that the old witch had actually got clear away without leaving the slightest clue.

A long controversy arose between Liebig and Lawes and Gilbert. However, by 1855 the following points were fixed with tolerable certainty, by the experiments at Rothamsted: (1) Crops do require, as Liebig maintained salts of the alkalis and the phosphates. (2) The composition of the ash of a plant does not furnish any information as to the soil constituents required by the plant. (3) Non-leguminous crops require a supply of nitrogenous compounds, ammonium salts, or nitrates. Without nitrogen in some form mineral manures are not effective in assisting the growth of these plants. (4) Leguminous crops are abnormal and do not require the addition of nitrogen in manure. (5) Soil fertility may be maintained for at least some years by means of artificial manures alone. (6) The benefit of fallowing is due to the increase of available nitrogen in the soil.

However, one must not underestimate the value of Liebig's work. Much of it was of very great value, chiefly in supplying data and analytical methods, and Liebig being a man of strong personality his writings stimulated other investigators into activity. Before he had finished his work many important facts of plant nutrition were settled, either by himself or by those aroused by his enthusiasm and industry. Thus Knop and others, by means of the culture of plants in water containing known amounts of various constituents, determined conclusively that the elements essential to plant growth are, potassium, magnesium, calcium, iron, phosphorus, sulphur, carbon, nitrogen, hydrogen and oxygen. Liebig's list differs from this only in the absence of iron and the presence of silicon. And recent experiments have shown the great value of silicon in growing cereals.

I have pointed out the importance of the observations made by Lawes at his farm at Rothamsted concerning the mineral theory of Liebig. This was not the only experimental farm of its kind. I have already alluded to the pot and plot experiments of Boussingault at his farm in Alsace which were commenced about the same time in 1830. However, Lawes' farm at Rothamsted has become world famous and has served as the model both in organization and in the nature of the work undertaken, according to which all subsequent experimental farms have been planned. The government experimental stations which have since become so numerous throughout the world are developments of the Lawes idea. Lawes secured the co-operation of a very capable scientist, Gilbert (afterwards Sir Henry Gilbert) and for over 50 years these men worked together along with a gradually increasing staff of chemists and workmen in performing the immense number of experiments which will be justly famous for all time.

Time will not permit me to give any but the very briefest account of the great work performed by Lawes and Gilbert. It includes careful experiments upon manures, artificial fertilizers, the fixation of nitrogen by the soil and by the plant, the chemical changes in the soil under various conditions, the study of various crop rotations, the composition of soils and the alteration of composition by percolating salt solutions and by the growth of various kinds of crops manured by various mixtures of artificial fertilizers and barnyard manure, the changes occurring during the bare fallow, the alteration of the physical texture of soils and its connection with improved cultivation

and aeration of soil, the determination of the toxicity of various compounds present normally in soils and of various compounds added to soils, the sterilization of soils and its effects, and a thousand and one other topics relating to plant growth. There are fields on the Rothamsted farm the chemical history of which has been recorded for over 60 years—the analysis of everything which went into the fields and everything which came out of them, manure, seed, crop including grain, straw and stubble, and in certain cases the composition of the drainage water running away. The value of experiments of this sort extending over such a long period is obvious. There is scarcely a problem of agricultural chemistry adapted to investigation in the field, to which the Rothamsted farm has not made important contributions. I can refer to only the general conclusions arrived at in the case of but one of these. I will choose one which has already exerted an influence on agricultural practice—the necessity of phosphates and the effect of added phosphates on crop yield. These results I have taken from the monograph "Soil Conditions and Plant Growth" by Dr. Russell, the present able director of the Rothamsted station.

Phosphates act on crops in two ways (1) root formation is promoted to a remarkable extent in the early stages of growth, thus developing an extensive root system, and consequently rendering more inorganic food available for the plant. The effect is particularly striking on clay soils where plants find greater difficulty in producing well formed roots, also under drought conditions by enabling the roots to grow rapidly into lower and moister layers of soil. It is believed that the marked effect of phosphates on the wheat crops of the dry regions of Australia is due to this expansion of the root system. All root crops as potatoes, turnips and mangels are assisted to a very great extent by phosphates. (2) Phosphates also hasten the ripening processes and for this reason they are applied to the wheat crop in the northern districts of England in order to bring on the harvest earlier and obviate the risk of loss by bad weather. The northern limit of growth of several crops may be extended in this manner. This effect of the hastening of the ripening process by phosphates is strikingly seen on the Rothamsted plots where the crops receiving phosphates are golden yellow in color while the others are still green. The following table shows very strikingly the effect of withholding separately phosphates, nitrates, potash salts, in comparison with plots treated with complete potash, phosphate, nitrate, manure, and with plots treated with dung. These experiments were all with barley on the same field for a period of 60 years commencing in 1852.

YIELD OF GRAIN IN 1,000 LBS. PER ACRE.

	1852-56	1857-61	1862-71	1872-81	1882-91	1892-01	1902-11
Dung.....	2.31	2.78	3.00	2.88	2.66	2.56	2.50
Complete Manure*....	2.47	2.71	2.67	2.34	2.24	2.02	2.25
No Phosphates.....	2.27	1.71	1.99	1.68	1.38	1.26	1.23
No Potassium.....	2.42	2.70	2.76	2.29	2.01	1.63	1.81
No Nitrogen.....	1.86	1.57	1.39	0.98	0.92	0.74	0.94

YIELD OF STRAW IN 1,000 LBS. PER ACRE.

	1852-56	1857-61	1862-71	1872-81	1882-91	1892-01	1902-11
Dung.....	2.82	3.15	3.35	3.37	3.28	3.35	3.54
Complete Manure* ..	3.29	3.17	3.14	2.63	2.61	2.36	2.83
No Phosphates.....	2.86	2.03	2.20	1.75	1.64	1.56	1.75
No Potassium.....	3.21	3.03	3.07	2.30	2.20	1.90	2.16
No Nitrogen.....	2.03	1.58	1.42	0.95	0.94	0.90	1.39

*Salts of Ammonium, potassium and phosphoric acid.

The effect of phosphate starvation shows itself in depressing the yield of straw and grain, the straw being the first to suffer. Potash starvation takes longer to set in, probably because the soil contains a larger amount of available potassium; it also affects the straw first. Nitrogen starvation sets in at once, rapidly bringing both grain and straw down to a low level. The effect of phosphates in raising the quality and feeding value of the crop is very great. The best pastures in England and France are those richest in phosphates. Paturel has shown that the best wines contain the most phosphoric acid salts and a list of the vintages arranged in the order of their phosphorus content was found to be almost identical with that of the wines arranged in the order of superior flavor by the wine merchants.

It is one thing to make these observations and another and more difficult matter to get behind these effects and determine their causes. Loew found that fats and albumen accumulated in the absence of phosphates and that cell division **does not occur**. Phosphorus is a constituent of the nucleus of the cell and is apparently required for cell division. Also the normal transformations of starch do not occur in the plant in the absence of phosphorus. Thus Reed found that starch was formed in the absence of phosphorus but did not change to sugars. Instead of sugars erythro-dextrin and cellulose were formed.

I have selected but one of a very great number of investigations extending over 60 years representing a truly colossal amount of work, which has accomplished a revolution in agricultural thought, and in many parts of the world a revolution in agricultural practice. The results obtained with regard to the use of nitrogen compounds and potassium salts are even more striking and valuable. Time will not permit me to deal further with the Rothamsted experiments, to indicate their comprehensive scope and the far-sighted vision of those great public benefactors, Sir John Lawes and Sir Henry Gilbert. Some conceptions of the importance of the applications of these results to practical agriculture may be gained by recalling the magnitude of the superphosphate industry, the stimulation to agricultural investigation resulting in the development of the potash deposits of the world and the successful syntheses of such nitrogen compounds as nitrates, ammonium salts, and calcium cyanamide, all of which under improved economic conditions could not only remove forever any fear of food shortage, but, if it were desirable, could produce food in wasteful abundance for the whole world. I shall return to this point presently.

The success of the Rothamsted experiments has resulted in the widespread establishment of government experimental stations in all countries making any pretence to promote the development of its agricultural industry. The United States and Germany are outstanding examples. In the more progressive of these stations not only are full scale plot experiments performed with a view to the immediate improvement of practical agriculture, but researches in pure plant physiology are carried out in the laboratory for the purpose of determining underlying causes—the function of potassium, phosphorus, nitrogen, calcium, etc. in plant growth, the nature of the gas exchanges, the function of the plant dyestuffs as chlorophyll, the mechanism of the action of oxidases, reductases and other enzymes in plants, in short, to determine the mechanism of plant growth. This more fundamental work, the value of which cannot be overestimated, is, however, but a recent development in the experimental stations and is carried out only in the older and more highly developed institutions. It is more intensively and extensively pursued in University laboratories of organic and physiological chemistry.

I must return now to the main road of my discussion. We have seen how Liebig set up his belief in the efficacy of chemical analysis as a complete means of determining the needs of a soil for crop production, and how the main tenet in that belief was rendered untenable by the experiments at Rothamstead and elsewhere. What was the matter with Liebig's mineral theory? Why was it erroneous? Some other factor

or factors must exist in all soils, which in the case of some soils are limiting factors, and which have nothing whatever to do with the chemical compositions of soils. A vast number of investigations have fixed some of these. Among them are (1) the physical properties of the soil, involving the proportion of soil particles of various sizes ranging from sand through fine sand, silt, fine silt, to clay. This carries with it the consideration of the humus content of the soil, and the phenomenon of absorption on matter in the colloidal state, the latter a very difficult problem in itself which has given rise to a large and very important branch of chemistry known as colloid chemistry. (2) The presence of toxic substances in the soil, produced either as a part of the plant metabolism or by the chemical changes in the soil of decomposing organic matter. Many of these toxic substances have been isolated and their effects studied in water cultures, in sand cultures, and in specially prepared soils. (3) The toxic effects of salts of various kinds. Very strange and significant results have been obtained by Loew, Osterhout and others on the effects of various concentrations of salts of potassium, sodium, magnesium, calcium, and other elements upon plant growth and more particularly the neutralizing of toxic effects by definite proportions of these salts. (4) The effect of the water content of the soil upon plant growth. This latter study has emphasized the very great importance of farm drainage in order to remove all surplus water over and above that which is held on the surface of the soil particles, and which cannot be removed by drainage, in order to permit of the proper aeration of the soil without which the chemical changes necessary to plant growth cannot take place, but are replaced by deleterious changes resulting in the production of toxic reduction products, and an acid soil. (5) The effect of cultivation in increasing soil fertility. That increased crops are obtained by drainage and by working of the land was known from the earliest times. However, cultivation was not sufficiently emphasized until in 1730 Jethro Tull, an Oxford man, insisted on its great importance, wrote a book called "The Horse Hoeing Industry" and invented the horse cultivator and seed drill. This was the birth of the great modern agricultural implement industry. The recent work in drainage and cultivation has told us some of the reasons that these promote growth. The chemical reactions of the soil requisite for plant growth have been sufficiently worked out to indicate, that a plentiful supply of oxygen is necessary to carry out these reactions. The decomposition of organic matter, the oxidation of toxic substances, the prevention of the further formation of toxic reduction compounds, the prevention of acid soils, all require a plentiful supply of oxygen. Any excess of water in the interstices of the soil which precludes the entrance of oxygen is thus very harmful and must result in diminished crop yields. No amount of manuring or cultivation can take the place of drainage. Drainage is the primary essential for crop production. Likewise investigation has shown some of the reasons that cultivation has such beneficial effects. Apart from the eradication of weeds, experiment has shown that the largely increased yields obtained by cultivation and the bare fallow are due to the increased nitrogen content of the soil. (6) The action of organisms in the soil. This subject of soil bacteriology is of the very greatest importance and perhaps more experimental work has been done in this field than any subject connected with soil chemistry with the exception of the action of fertilizers. I shall trace briefly the history of this branch of agriculture.

Liebig believed that all the changes in the soil are purely chemical in nature. Shortly after 1860 great advances were made in general bacteriology. This led Pasteur to the opinion that many of these such as the decomposition of organic matter are due to the action of bacteria. Schloesing and Muntz in 1877 proved that bacteria are active in the production of nitrates in sewage. Warrington applied this knowledge at the Rothamstead farm to soil processes and showed that ammonium salts in solution can be converted into nitrates by adding a little soil. He found two processes were occurring, and two distinct organisms at work. The first consists of the transformation of

ammonia into nitrites and the second the change of nitrites into nitrates. Notwithstanding years of work Warrington failed to isolate these two organisms. It was not until 1890 that Winogradsky succeeded in isolating them and showed that Warrington's failure was due to the fact that the organisms will not grow in the culture solutions used by him. Warrington, however, further showed that in whatever form the nitrogen is supplied to the soil the plant only assimilates it after it has been converted into nitrates by the soil organisms. In 1888 Hellriegel and Wilfarth performed their celebrated experiments which proved that leguminous plants as peas, beans, clovers, have the property of receiving a large part of their nitrogen supply from the inert nitrogen of the atmosphere. They are able to fix atmospheric nitrogen. The growth of oats, barley, and other non-leguminous plants was found directly proportional within limits to the nitrate supplied, while in the case of leguminous plants no such relationship was found. The leguminous plants grown without nitrates all reached the seedling stage. Then some died while others continued to grow. Analyses for the nitrogen content of plants and soil after the experiments showed, that in the case of oats and barley there was a small loss of nitrogen, while in the case of leguminous plants as peas there was a distinct gain in nitrogen, although no nitrogen compounds had been added to the soil. Two conclusions were drawn by Hellriegel and Wilfarth; (1) the leguminous plants take nitrogen from the air and fix it as compounds in the plant, (2) there is some other factor in operation in nitrogen assimilation, which in their experiments was present only by chance. In order to arrive at an explanation Hellriegel and Wilfarth made use of two facts (1) the observation of Berthelot that micro-organisms exist in the soil which can fix atmospheric nitrogen, and (2) the fact known to the botanists of the time that there are nodules on the roots of the leguminosæ family which contain bacteria. As a working hypothesis they supposed that the bacteria of the nodules of leguminosæ can fix nitrogen and transfer it to the plant in such a form that the plant can utilize it. This hypothesis led to experiments which resulted in the following observations: (1) In sterilized sand and in the absence of nitrates peas made only small growth. When nitrate was added the growth behavior was like that of oats and barley—growth proportional to nitrate added. (2) Peas grew well and developed nodules in sterilized sand to which a water extract of arable soil was added. (3) Peas grown in unsterilized sand without soil extract and without nitrate sometimes did well and sometimes failed to grow. The conclusion was that leguminous plants if inoculated with soil extract containing bacteria can develop nodules containing bacteria which have the capacity of fixing free nitrogen and that the erratic behavior of peas in unsterilized sand was due to the chance presence of the necessary bacteria to infect the roots and produce the nodules. Gilbert who was present at the meeting of the National Science Congress at Berlin in 1886, where Hellriegel and Wilfarth presented their epoch-making paper, and exhibited their plant specimens, returned to Rothamstead and repeated the experiments and confirmed them in every detail. It just remained for Schloesing and Laurent to show that the weight of nitrogen absorbed from the air is approximately equal to the gain in nitrogen by the plant and soil, to finally and completely settle the whole question. And so another chapter in science was brought to a brilliant close. A very great deal of further work has been done upon soil bacteriology which seems to justify the belief that there is a very close relationship between bacteria and plant growth. Whether we can go so far as to say with Wollny, Berthelot and Laurent that the bacteria make all the food in the form necessary for assimilation by the plant, is a matter of dispute. It would seem superficially that this might be settled quite simply by sterilizing a portion of the soil, either by heat or by some volatile sterilizer, as carbon bisulphide or chloroform, grow plants in sterilized and unsterilized soil and observe the effect. But the problem may not be settled in such a simple manner. Heating or sterilizing by volatile agents alters the soil. It destroys the bacteria but it also results in the production of new compounds especially in a humus soil, some of which are toxic,

and the whole matter is further complicated by the fact that there are many kinds of bacteria, and some of them as the protozoa are very harmful as they inhibit the action of the good bacteria. A sterilization of the soil containing both will remove all, unless great care is taken, the completely sterilized soil used in a pot experiment can easily become inoculated with the good bacteria, resulting in such a tremendously accelerated growth of the good bacteria, owing to the absence of the bad ones, that the sterilized soil will show a very much augmented plant growth. Indeed this sterilization of soils is a matter which has received much attention from experimenters of late and promises interesting results. This all shows once more the great care which must be taken in performing experiments in plant physiology and in drawing conclusions from them. It is exceedingly easy, as Van Helmont, Liebig, and many other very able men have found, to fall into traps which old Dame Nature dearly loves to place in the path of the investigator.

With regard to the many reactions taking place within the plant itself, time will not permit me to make more than the briefest reference. Here we find a mechanism which is capable of taking relatively simple compounds as nitrates, carbon dioxide, oxygen, water, and the salts of potassium, phosphorus, magnesium, sulphur, and iron, and with the help of radiant energy work them up into a large number of the most complex organic compounds such as fats, carbohydrates, proteids, plant dyestuffs, plant acids and bases, which have been found in plants. It has been the chemist's task (1) to separate and identify these individual compounds and determine their constitutions by a study of their chemical properties and by their synthesis from simpler compounds of known constitution. (2) To utilize this information in the study of plant reactions with a view to definitely determining what the chemist calls the mechanism of the plant reactions—the successive stages in the synthesis, within the cell, of a complex compound, from the relatively simple elements and compounds which the plant has at its disposal. For instance, through what successive stages does the nitrogen of nitrates pass from the time it diffuses through the fine root hairs of a plant till it is found constituting a part of the complex molecule of a proteid in the cell of a leaf, or what are the various factors which make possible the transformation of carbon dioxide and water into sugar and starch, and how do they operate, or again, what is the function of potassium or phosphorus or of any other of the other inorganic constituents in the plant reactions, or again what is the mechanism by which the many long chains of interdependent equilibrium reactions are so rapidly adjusted when the equilibrium is disturbed at any part of the chain? These and a thousand and one other problems having to do with the reactions taking place within the plant must be solved before we can have anything resembling a complete picture of the mechanism of plant growth, and be able intelligently to influence and improve it. I do not wish to appear in the slightest degree to belittle the field experiments of the experimental stations. I wish to point out, however, what every investigator in those experimental stations who reflects at all upon his problems must admit, that the work of the chemist of the experimental station is raised out of the plane of hit or miss experimenting, of mere empiricism into the plane of scientific investigation, just in so far as he has exact scientific information with respect to the plant mechanism with which he is working. There has not been too much assistance given to agricultural station work but there has not been enough assistance given to promote the more fundamental work of the chemist, the physicist, and the plant physiologist. Up to the present the work of the chemist has been chiefly concerned with the problems of class 1. An immense mass of data has been accumulated respecting the separate compounds of plants and their constitutions. Much of this has had a great influence upon chemical industry. It is only necessary to mention the very great development of the synthetic manufacture of indigo and alizarin and their derivatives, the synthetic essential oil and artificial perfume industry, and the beginnings which have been made toward the commercial

synthesis of rubber. Here we find examples of a number of plant products having a very large commercial use, whose constitutions have been determined and for which commercial methods of synthesis have been devised. In some cases these factory products on account of the cheapness of manufacture and uniformity of properties have entirely superseded the plant products, while in other cases, as for instance, rubber, the plant product still excels the synthetic product in both quality and cheapness of production, and seems destined to excel it for some time to come.

In the second group of problems, although many individual facts are known, we are in a very much less satisfactory position. A beginning has been made upon the great picture of the mechanism of plant reactions, but it is only a beginning. For instance, the chemical constitution of chlorophyll, the green coloring matter of the leaf, has recently been worked out by Willstätter and his students, and it has long been known, that it is a factor in the so-called assimilation of carbon process whereby the carbon dioxide of the air is transformed into sugar and starch, but we know very little about its exact part in the mechanism. Again, it is known that potassium is a constituent of the nucleus of the cell in the growing parts of plants, but what function it performs there or through what reactions it has passed in reaching that position, are unknown. Again, magnesium is a constituent of the chlorophyll molecule but by what series of reactions it has passed from the state of a simple magnesium salt in solution into the complex molecule of chlorophyll is unknown. Again, a great many of the plant reactions are known to be brought about by the action of plant catalysts called enzymes, many of which have been isolated and the conditions under which they act studied, but the underlying causes which confer this remarkable property of accelerating definite chemical reactions upon definite enzymes, is as yet wholly a mystery.

I have endeavored in this very brief outline of the development of chemistry in its application to agriculture, and in selecting out of a great mass of material a few outstanding topics which I have considered in slightly greater detail, to give you some idea of the way in which the investigator works, and a few of the conclusions he has reached. You will readily understand that what I have given is but a small portion of the total picture of what has been accomplished. You may believe me when I say that the mass of data collected is truly colossal. To compass this subject is particularly difficult today, for, although agricultural science has made very great progress in collecting data, comparatively few generalizations have been discovered by which these facts have been co-ordinated and to which they may be referred. In view of the highly developed state of many branches of Physics and Chemistry why have plant physiologists not made greater progress in unravelling the mechanism of plant reactions and plant growth, and not established more generalizations underlying their very numerous experimental observations? I think that the reason lies in the great complexity of the system with which they always operate. The simplest of their experiments are performed with a whole plant, a leaf of a plant or with a single cell or group of cells. But consider the immense complexity of even a single cell. Here we have a water medium containing a large number of electrolytes and non-electrolytes in solution, with also both suspensoids and emulsoids in colloidal solution, with also precipitated suspensions and emulsions with their enormous surface carrying absorbed electrolytes and non-electrolytes, the separate compounds in solution and the several phases kept in equilibrium by the action of minute quantities of catalysts and enzymes, the whole structure, moreover, constituting a complex organism with the power to undergo fertilization and thereby propagate and reproduce its kind, in short endowed with all the extraordinary phenomena of the life process, superposed upon this physico-chemical complex. The unravelling of this labyrinth of reactions, conditions and factors at work here, by the study of the plant or cell, seems quite beyond the limit of human accomplishment. The variables are too numerous. Moreover, they are not all known. Hence in any experiment some factor quite overlooked may be the

determining one, while in another the result may be due to the conjunctive operation of several factors very few of which can be estimated or even guessed at. To make any progress in the solution of this complex problem of the mechanism of plant reactions, the natural order is obviously first to attack and solve the fundamental problems underlying it, such as the nature of solution, colloidal state, of catalysis, etc. That is to say, by working with simple systems or more correctly, simpler systems (for even these are complex enough) such as a simple electrolyte or non-electrolyte dissolved in water determine the real nature of the several states of the solute at all concentrations, or with a simple amorphous precipitate as silicic acid or ferric hydroxide determine the state of the surface water surrounding each particle and the mechanism by which these precipitates accelerate reactions and under what conditions they facilitate oxidations, reductions and hydrolyses. From this the chemist could then pass to the mechanism of catalysis and enzyme action and last of all consider the very complex cell of an organism itself where all of these phenomena are found associated together. Only in some such way can real progress be made in the difficult fields of plant and animal physiology. Scientific men will then be in a position to make an intelligent application of science to the treatment of disease and the elevation of agriculture from the state of an empirical art to an industry with a real scientific basis.

Vastly greater assistance should thus be given by the government to investigation work in all branches of Physics and Chemistry, so as to solve the basic problems of these sciences and thus lay the foundation for a more rational and rapid advance of medicine and agriculture. The great problems which remain in the treatment of disease and in the improvement of plant growth will not be solved in hospitals or experimental farms until the more fundamental problems of Physics and Chemistry to which I have referred, and which underlie these sciences, have first been solved. Without reference then to any higher motives such as the development of Physics and Chemistry as an aim sufficient in itself to engage the best energies and abilities and to justify the most generous support, a vigorous appeal backed up by the strongest kind of evidence should be made to the government by all sorts of organizations, especially by scientific organizations such as this Society of Chemical Industry, to convince the government that it is not only desirable to develop the sciences as such, but it is in the highest degree "good business" to do so. I feel sure that if the very close connection between scientific investigation of the fundamental sort, and real material progress were pointed out, and emphasized, that vastly greater assistance would be given to accelerate this work. Assistance is more readily secured for experimental farms and hospitals because the layman, who thinks he is eminently practical, can appreciate the connection between progress and the sort of research carried out in such institutions. Were it possible to convince him that when he refuses assistance to the one and supports the other he is acting in a most unpractical way, that he is to a very large extent diminishing the prospects of practical results in the one which he does support, then his common sense must tell him that in order to restore his very rapidly diminishing reputation for being practical he must support to at least an equal extent, both branches of investigation. The results accruing to medicine, agriculture, and industry could not be otherwise than very great, and might conceivably be tremendous and epoch making. A solid basis of facts and generalizations would be provided upon which the investigator in plant growth and in medicine could build and which might effect very great advances in the treatment of disease and in increasing the production of food stuffs. What this might mean to mankind could not be overestimated. However, nothing will be accomplished in such work in this country unless provision is made for it by the government, to an extent greatly exceeding the very meagre support given at present. An adequate development of this great work will be possible only when the country comes to the realization that research is the most powerful instrument which man possesses for material progress,

and that it places an instrument of incalculable power in the hands of any nation which efficiently organizes and develops it.

The agitation throughout the world for the more intensive prosecution of research has led to a restatement of a curious misapprehension regarding the aims of science. The fact that the results of scientific investigation may be, and often are, used for the mere speeding up of life, the wrongful exploitation of the public domain, or even for purposes of destruction, gives absolutely no support to the statement, that one frequently hears, that science is grossly material and robs the world of something for which no amount of material progress can possibly compensate. This is an utterly false and superficial estimate, and shows a complete ignorance of the real goals towards which science moves. That science should impose a burden of any kind upon mankind or even result in the exaggerated emphasis, which many believe the present age, places upon material development, is unfortunate. But these are matters with which science is not concerned, and for which science is not responsible. Such consequences are not inherent in science, and are not the inevitable accompaniments of science, as some would have us believe. They are the result of the general stubborn selfishness of mankind and have to do with man's moral development and not with his scientific accomplishments.

We have seen the desirability of expanding our knowledge in Chemistry, Physics, plant physiology, and agriculture by investigation work. The question naturally arises, are we utilizing all the information which investigation has given us and which is already at our disposal for the improvement of agriculture and the increase of crop production. It is unfortunate, particularly at this alarming juncture of the world's affairs, to be obliged to answer this question with an emphatic no. In view of the very serious consequences which this failure entails, it behooves thinking men to examine into its real causes. The means at the disposal of the farmer for increasing his crop yields are of four general kinds—those pertaining to (1) drainage, (2) cultivation, (3) use of artificial fertilizers, (4) seed selection and sterilization. There is no doubt whatever of the great importance of each of these factors, and an immense amount of investigation both in the laboratory and the field has made it very clear, the methods by which the beneficial effects of each factor may be obtained. This information has been worked out in great detail and is found in the bulletins issued to farmers by the agricultural departments of all the governments of the world. Let us examine each factor more closely.

Drainage involves first a farm survey in order to determine the general directions of the main drains, their proper outlets, their size and levels. This work is sometimes done free of charge by a government representative. This is the easiest part of the whole proceeding. The farmer's troubles now commence. He must first secure good tiling. The quality of the tile he purchases is a matter of chance. He has no methods for testing its strength or stability except some crude practical suggestions which he may have picked up in conversation with his fellow farmers. There is no guarantee of uniformity of product. One batch of tile may be properly made and another be without any durable qualities at all when covered up 5 feet underground. The farmer finds this out by the failure of his drain which entails a ripping up perhaps of several hundred feet of it buried anywhere from $2\frac{1}{2}$ to 6 feet in the ground. His next trouble is in digging the drain. It is, for obvious reasons, out of the question today for a farmer to consider the digging of drains by hand labor. Moreover, it should not be necessary with all the efficient ditching machinery which has been devised and which is manufactured. Let us suppose, however, that the farmer has constructed his main drains and has brought them to the public highway. Here he probably finds an apology for a ditch—one that is useless to carry off his drainage water. He must either construct at his own expense several hundred feet of ditch with large size tile beside the public highway, or apply to the township council for this work to be done, and probably be

refused. He rather thinks that there is some legal machinery somewhere by which he could get an enforcement of the Ditches and Drainage Act but that involves a large expense for lawyers' consulting fees, engineer's fees, expenses for the application of legal pressure, and with always the possibility that perhaps some exceptional conditions pertaining to his particular drain, as for instance its depth or its relation to a railroad embankment or a dozen other details, may vitiate his claim. This legal aspect of drainage is very important and stands as a decided impediment to the more extensive use of drains on farms. It embraces not only the mutual obligations and rights of the farmer and the township council, but the relations of farmers on adjoining properties. It seems then that, with respect to drainage, the following improvements should be made: (1) the provision of tile, made according to standard specifications and conforming to simple standard tests, thus securing uniformity and durability; (2) the provision of ditching machines which might be stationed at agricultural centres for use in the district; (3) the proper maintenance of ditches to carry the drainage water away from adjoining farms; (4) the publication of a bulletin of farm law which would explain in language devoid of legal forms and terms the rights and duties of farmers, township councils, roadmasters, county engineers, and such other simple legal information now either difficult to obtain by the farmer or obtainable only with great trouble and expense.

Coming now to cultivation we find that the farmer does not require to have its benefits explained to him. His own experience has impressed him with its importance. He knows the greatly increased yields obtained by repeated ploughing and cultivation during the season. And yet not 5 per cent of the farms in this province are sufficiently worked. Indeed more and more good land is being put into pasture with a consequent diminution of cereal production. This is not the result of scarcity of labor alone, although this is a large factor just at present. It is due, to an equal extent, to the insufficient use of cultivating machinery and of power tractors for hauling it. This involves the consideration of the agricultural implement industry and the tariff. I will not here make any suggestions as to the solution of this problem. I merely wish to state the fact that the very great value of cultivation for increasing foodstuffs is known, that the machinery for cultivation and the power tractors for hauling it have been devised and are being manufactured and sold, and yet but a small fraction of the benefits to be derived from the use of cultivation machinery is actually realized.

With respect to the third great factor in increasing crop production, the use of artificial fertilizers, the conditions are still more unsatisfactory. In this department of agricultural chemistry perhaps more investigation work has been done than in any other. The results to be obtained in increased production of roots, cereals, and grasses by the use of artificial fertilizers, are very great indeed, especially when this use is combined with proper drainage and cultivation. The materials to be employed, the methods of application, and the results which may be realized, are all described in the bulletins issued by the departments of agriculture. And yet with the exception of a few market gardeners in the neighborhood of large cities, or in potato regions the use in this country of these valuable fertilizer materials is negligible, and this notwithstanding the large packing houses with their refuse rich in fertilizer constituents, the large deposits of phosphate rock and of limestone, the cheap waterpower for the manufacture of nitrates and calcium cyanamide, and the thousands of tons of fish refuse going to waste every year on both the Atlantic and Pacific coasts and on the shores of the Great Lakes.

I am not here to discuss the great agricultural industry on its economic side, to deal with the difficult questions of tariff, trade, transportation, labor, and the regulation of profits, or to suggest remedies which might be applied. I leave that for specialists in economics. But I do wish, especially in view of the existing world food shortage, to point out the following very significant facts. (1) that the practice and science of agriculture has accumulated a stock of information respecting the use of artificial

fertilizers, drainage and cultivation, which if applied to the land now under cultivation would simply glut the markets of the world with food; (2) that the raw materials required are either present in very great abundance or can be manufactured by well known processes requiring electric power; (3) that extremely efficient machinery has been devised and is being manufactured and sold whereby all the mechanical operations necessary, can be quickly and effectively carried out. I do not wish to leave the impression that this increased crop production could be obtained in one year or even two years. The organization and setting in operation of the huge industries involved, and the solution of the thousand and one problems would be difficult enough, even were the whole question not further cumbered with such controversial questions as tariff, transportation, labor, and the private control of industries relating to agriculture. With these complications the matter seems almost hopeless of solution by agreement. But I think it is equally obvious that unless the elements which stand in the way of a settlement of this problem of making a great reform possible in the production and distribution of foodstuffs, realize, that agriculture is not an ordinary competitive industry but a great basic industry, very serious consequences will result. Surely we are able deliberately to set out and travel at least some considerable distance along the path of economic reform, and thus avoid the possibility of presenting this mean spectacle to history, of stubbornly combatting reform, until step by step we are driven to it by the pressure of circumstances when no element of choice remains.

I have tried to indicate to you how scientific men from early times have striven, in most instances with no thought of financial gain, to determine the mechanism of plant growth and thus contribute to the upbuilding of agriculture. Surely the day is past when the business man would simply appropriate scientific information and utilize it for private gain without regard to his obligations either to science or the state. I would plead, therefore, for greater assistance for research in all branches of science, and for an endeavor on the part of the business interests to see that such economic and other reforms are instituted, as will make the results of investigation available for the welfare of humanity.

THE UTILIZATION OF THE PEAT RESOURCES OF CANADA

BY B. F. HAANEL.

An abstract of a paper delivered before the Montreal Branch of the Canadian section of The Society of Chemical Industry by Dr. B. F. Haanel, of the Mines Branch, Ottawa, on December 14th, 1917, and reported in full in the Journal of the Society of Chemical Industry, vol. 37, No. 15, p. 258, August, 1918.

The total area of Canada covered by peat bogs has been estimated at 37,000 square miles and the average depth of the peat deposits may be placed at 6 feet. Of this area 12,000 square miles are situated in the Central provinces. On a basis of actual heating value these latter available deposits are equivalent to over five billion tons of anthracite coal. During the last ten years fifty-eight Canadian bogs have been mapped by the Mines Branch, Ottawa, and it is known that excellent bogs are conveniently situated with respect to all our thickly inhabited districts in Canada.

Past efforts to create a peat industry have shown that the larger portion of the

capital lost could have been saved and a flourishing peat industry established if the promoters had been advised by engineers who understood their business.

DESCRIPTION OF PEAT.

Peat is a substance formed by the incomplete decomposition of vegetable matter either in, or in the presence of water. Different forms of plant life may be represented by strata in any given bog. In a well humified peat bog very few traces of the original plant structure may remain and in this state possess many of the properties of a colloid. The production in this way of hydrocellulose, a true colloid, with the property of absorbing much water is of great importance in determining the proper method of manufacturing a peat fuel. The results of uniform chemical operations are never found throughout an entire bog. The ratio of solid and water in a peat bog is one to nine and the real problem is reduced to the economic disposal of this moisture.

MANUFACTURE OF PEAT FUEL.

All attempts to remove water in peat by pressure have been unsuccessful. Processes employing artificial heat and pressure are uneconomical and must result in failure. M. Ekenberg, a Swedish chemist, directed the expenditure of several million dollars of English and Swedish capital in unsuccessful efforts to produce a fuel by variations of heat and pressure treatments. The only economic process yet discovered is that which uses the sun and the wind for removing moisture. The product thus made is called "machine peat," and the method of working was demonstrated by the Government at Alfred, Ontario.

The following steps were used in the process—

- (1) Excavating raw peat by hand or machinery.
- (2) Transferring to hopper with special macerator.
- (3) Spreading the pulped peat to dry.
- (4) Cutting spread peat into bricks when properly set.

The macerator used consisted of a cylindrical shell within which was a set of special rotating knives operating with a fixed set of knives attached to the cylinder. The machine cuts fibres and causes thorough mixing.

In drying the hydrocellulose binds the particles of the peat together, forming a concrete whole which prevents the re-absorbing of moisture during wet weather interruptions. A colloid skin covers the outside of the block which acts as a vehicle for conveying the moisture from the inside of the brick to the air and equilibrium is maintained until drying is complete. In their experimental work the Department of Mines manufactured 3,000 tons and the opinions of users of this fuel were published by the Canadian Peat Society in their Journal. The estimated cost on a strict business basis, would be \$1.70 per ton on the field.

PROPERTIES OF PEAT FUEL.

Peat makes a clean fuel, leaving no soot and a low ash. Clinkers are never formed and the fuel ignites readily. The relation between anthracite coal and peat fuel as regards heating value per pound is 12,500; 7,000 or 1.8:1. The volume of peat required to equal coal is about 3.6 to 4 times that of the coal. The nitrogen content of peat containing 25% moisture is about 1.3%.

Peat has been and can be used for very nearly all the purposes for which coal has been the only fuel used. The use of peat fuel and peat coke will increase as coal becomes scarcer and this period is rapidly approaching. In gas producer plants the problem is simply one concerning the relative cost of peat fuel and other fuels obtainable.

In by-product recovery plants the production of ammonia is one of the governing factors or may be the governing factor. Some peat bogs carry 2 per cent. of nitrogen and these would be specially valuable for such exploitation. In Italy and Germany plants have been erected for generating electricity and recovering ammonia from peat fuel. The tars obtained as by-products in these plants were burned under the boilers. We have several bogs near some of our industrial centres which run high in nitrogen and where failure would be next to impossible if they were developed on a sound business basis, but the capacity of the installation would need to be at least 4,000 horse power. The low heating value of peat fuel makes it essential that it be used close to its source of manufacture. If the production of gas were considered as the primary object a plant suitably situated with respect to a city or group of towns could supply gas for heat, light, and power purposes. A plant such as is now operating at South Staffordshire, England, and supplying gas from low grade coal could easily be erected in this country.

To a certain extent peat might be used as a source of oil to supplement our scarcity of immediately available petroleum in Canada. In the manufacture of peat coke, as conducted in Germany before the war, light and heavy oils, along with a number of important fractions and by-products were obtained. The possibility of utilizing peat in any particular way may now be readily determined.

THE ESTABLISHMENT OF A CANADIAN PEAT INDUSTRY.

There have been failures made in establishing a peat industry in Canada and as a country we cannot afford to have any more attempts terminate in this way. No effort should be made to manufacture peat fuel without the aid of a well recognized peat engineer—one who is thoroughly familiar with the laying out of a bog, and competent to handle the design and erection of machinery. Experimentation should be left until some well-tried economic process has been securely established.

If care is taken, in various lines involved, to consult specialists, when erecting chemical, metallurgical or power plants, designed for the exclusive use of peat fuel, failure will not result and the erection of one successful plant would lead rapidly to others.

"Finally, the people of Canada should be educated to realize the necessity of utilizing their own resources, even at some sacrifice in the beginning, instead of those obtained from foreign source. In fact this idea appears so important that I would even advocate Government legislation which would assist in, and insist upon the utilization of our own natural resources."

THE WASTE SULPHITE LIQUOR PROBLEM

BY BJARNE JOHNSEN AND O. F. BRYANT.

Being an abstract of a paper given before the Montreal Branch of the Canadian section of The Society of Chemical Industry on Friday, January 25th, 1918, and published in full in the Journal of the Society, vol. 37, No. 9, page 129, May, 1918.

The utilization of the 50 per cent. waste in wood which occurs when making sulphite pulp has always been a problem especially in countries which do not possess large forests and where it is impossible to discharge sulphite liquor into rivers. The

object of this paper is to report on some modern processes which might be introduced with advantage into Canada.

The reactions taking place during the cooking process are at best very complex and numerous. Many variable factors control the composition of the waste liquor such as wood variations and methods of cooking. Waste sulphite liquor has a specific gravity of about 1.05, is acid in reaction, has strong reducing power, and contains about 12 per cent. of organic and 1 to 1.5 per cent. of inorganic substances. Sulphurous acid is present both free and combined, but mostly as sulphonic acids. About 740 gallons of liquor will drain off from the blow pits per ton of pulp.

Where river discharge is prohibited the total solids are obtained by more or less complete evaporation. The concentrated liquor is a tar like substance with binding properties and has been used as a road binder and dust preventive. When the concentrated liquor is to be used as a binder for powdered fuel, fine pyrites, or foundry core sand, the lime must be removed by the addition of sulphuric acid followed by filtration.

The product known as "Cell pitch" is made from waste liquor neutralized and filtered through coke and concentrated. An adhesive may be produced after the addition of zinc carbonate or oxide, or by precipitation with glue or albuminous substances. A tanning material is obtained after concentration to 30 degrees Baume but it is necessary to remove lime, iron, free and loosely combined sulphurous acid. These extracts reach the market as "Sulphite Extract", "Spruce Extract", "Norego," etc., and it is claimed by tanners that they do not contain tanning and are of no value, but when these sulphite extracts are used with quebracho extract, the more difficultly soluble portions of the quebracho, namely, the phlobaphenes, are dissolved. For certain leathers imported tanning extracts from waste liquors are used extensively in Canada.

By the Strehlenert process a fuel may be made from waste liquor by the precipitation of the lignin compounds at high temperature and pressure. By this process only 75 per cent. of the total solids are precipitated and under Scandinavian plant conditions the cost is estimated at \$2.88 per short ton. Under Canadian conditions the cost is estimated at \$6.35 per short ton, having a B.T.U. value of 14,400. This is not likely to attract capital here while in Scandinavia conditions are favorable to the development of the process. This fuel or precipitate gives on distillation 56 per cent. charcoal and 18.7 per cent. crude acid, which in turn contains 1 per cent. methyl alcohol, 0.12 per cent. acetone, 1.43 per cent. acetic acid and 0.014 per cent. formic acid.

The process which has been given the most consideration in America is the manufacture of ethyl alcohol from the waste sulphite liquor. The amount of fermentable sugar varies between 1.5 and 2 per cent. On the average only about 1 per cent. of alcohol is obtained on a commercial basis although the Marchand process is said to give 1.25 per cent. of alcohol. The free sulphurous acid, which is strongly toxic to yeast is partly removed by evaporation and partly by neutralization to a point of acidity favorable to fermentation. Extrow's and Wallin's patents use some lime with a final addition of calcium carbonate. Marchand uses barium carbonate while Landmark uses calcium carbonate only. It is necessary to increase the amount of phosphates and nitrogen present before yeast will grow. In the Landmark process, milk or whey is heated with acid and the "lignocasein" filtered off. This product is used in paper sizing and the filtrate is used in the liquor to stimulate the growth of the yeast.

It is estimated that the total cost of one Imperial gallon of 100 per cent. alcohol made in Canada would be \$0.220; \$0.251, \$0.321 on the basis of a 30,000; 20,000 and 10,000 ton pulp mill respectively. The crude sulphite spirit contains about 3 per cent. of methyl alcohol. This would not interfere with industrial uses.

Alcohol plants are already established in various countries as follows: Norway,

two; Sweden, four; with a production of one million gallons per year; Germany, thirteen; United States, two; Switzerland, one.

The total solids are low (11-12 per cent.) and the economy of most of the processes depends upon the cost of concentration. New types of evaporators are appearing and Omon has announced a freezing method of concentration.

The Canadian Sulphite Pulp industry consumed in 1916 about 728,000 cords of wood. This meant a loss of 1,000 tons of wood substance daily and it shows that it would mean a tremendous saving for Canada if existing processes could be adopted or new methods developed by which this waste could be eliminated.

THE DETERMINATION OF CELLULOSE IN WOOD*

BY BJARNE JOHNSEN AND R. W. HOVEY.

In general the method of estimating cellulose is similar to the commercial process for the manufacture of wood pulp. Both are based on the high resistance of the true cotton cellulose towards chemical reactions such as hydrolysis and oxidation, and the comparatively low resistance of the non-cellulose substances. Difficulties arise in producing a perfect separation.

The authors proceed to a discussion of Cross and Bevan's chlorination method as one which has been used in scientific investigations and adopted by the industry. Advantages of the method are pointed out, but it is shown that differences in technique have produced results hardly comparable. From work on Canadian woods it was thought that a standard method might be found for future investigations.

The development of the work of Cross & Bevan is shown. They worked with jute which they considered as the typical form of "lignocellulose." Chlorination of the lignin group gave a lignin chloride of the empirical formula $C_{19}H_{18}Cl_4O_9$. When sodium sulphite was added to the chlorinated product a red color was produced which can be considered as the most typical lignin reaction. Previous results have shown that it is important to reduce the time of chlorination to a minimum and that the removal of all the lignin may only be effected by intermittent treatments with chlorine and sodium sulphite. By means of a special wood rasp suitable uniform sawdust was prepared and the results of Sieben & Walter (Papier-Fabr, 1913, 11, 1179) were verified on Canadian species. Sieber and Walter have standardized the method by leaving the fibre always in the same vessel. A description of their specially designed Gooch crucible is given. The use of this crucible gives high values compared with other methods and commercial practice. This indicates other non-cellulose substances in the residue. These furfural-yielding impurities may be removed by inorganic acids or alkalis but the cellulose is seriously attacked during the operation. It was found, however, that certain organic acids do not destroy the cellulose. Acetic acid and glycerin hydrolyses the lower carbohydrates and a large proportion of the furfural-yielding substances without attacking the cellulose. Curves showing effect of hydrolysis by the above method at 137 degrees C. are shown. The following is the method adopted by the authors for the determination of cellulose: "Two samples of about one gram each of air-dry sawdust, passing an 80 mesh but not a 100 mesh sieve, are weighed exactly, transferred to small flasks, and heated on a water bath for half an

*An abstract of a paper presented to the Montreal Branch of the Canadian Section of the Society of Chemical Industry on January 25th, 1918, and published in full in the Journal of the Society of Chemical Industry, Vol. 37, No. 9, page 132, May 15th, 1918.

hour with alcohol, filtered into the crucibles, and washed with hot alcohol. The samples are then transferred from the crucible to 150 c.c. flasks and covered with about 75 c.c. of the mixture of glycerin and acetic acid and heated in an oil bath at 135 degrees C for four hours, using long glass tubes as air condensers. The material is then collected in the crucibles, washed well with hot water, and the crucibles after cooling placed in the chlorination apparatus in which they are connected with the source of chlorine in such a manner as to prevent escape of the gas into the laboratory. The gas is now passed through the crucibles for 20 minutes, after which the free chlorine is removed from the material by washing once with a cold, dilute solution of sulphurous acid in water. The crucibles are then placed in small beakers which are filled not quite to the top of the crucibles with a 3 per cent. solution of sodium sulphite and heated in a water bath for forty-five minutes. The material in each crucible is washed with hot water, using a filtering flask, and after cooling, the chlorination process is repeated in the same way three times, the periods of chlorination being first 15, then 15, and finally 10 minutes. After the last treatment with sodium sulphite the fibres, after being thoroughly washed, are dried at 105 degrees C. for four hours or to constant weight and weighed in closed weighing bottles. The residue are calculated in percentage of bone-dry wood, the moisture of the original sawdust having been determined in a separate sample by drying about two grams of the material for four hours at 105 degrees C."

Analytical data showing cellulose content of some Canadian woods are given with comparisons of residues obtained by the two methods. Cellulose variations in balsam fir were followed from pith to bark and the analysis is given of a special disk showing normal growth. The analysis of aspen attacked by the fungus *Fomes ignarius* would show that the cellulose had been somewhat broken down and the furfural-yielding substances also attacked.

Samples of aspen and balsam fir were given exhaustive analysis after various special treatments. None of the reagents used extracted a single uniform substance. From the analysis made it was evident that there are striking differences in the chemical composition of balsam fir and aspen.

"The broad-leaved trees give a considerable higher yield of furfural than the coniferous woods, which latter contain much more substance yielding methylfurfural."

The paper closes with some suggestion on modifications regarding the terminology of the chemistry of wood and a short discussion of the views of Wislicenus and Klason on the relationships which may possibly exist between some constituents of wood.

MILK POWDER--ITS MANUFACTURE AND USES

BY S. B. TRAINER.

MILK powder to many suggests a composition of various chemicals to produce a product that can be used as a milk substitute. It is, however, one of the important articles of food produced from liquid milk. Of all the foods used today everywhere milk takes the leading position. Someone might suggest flour as the leading food but it must be considered from the point of view of food value. From the point of view of food value milk is the leading daily food of the world.

Comparative analyses of milk and milk powders are as follows:

LIQUID WHOLE MILK		LIQUID SEPARATED MILK	
Water.....	88½%	Water.....	91.00%
Fat.....	3½%	Fat.....	.03%
Milk Solids.....	8½%	Milk Solids.....	8.97%
<hr/>		<hr/>	
100 %		100.00%	

WHOLE MILK POWDER		SEPARATED MILK POWDER	
Casein.....	20.99%	Casein.....	29.90%
Albumen.....	4.01%	Albumen.....	8.70%
Milk Sugar.....	38.10%	Milk Sugar.....	50.90%
Fat.....	28.83%	Fat.....	.32%
Ash or Salts.....	6.13%	Ash or Salts.....	8.53%
Moisture.....	1.94%	Moisture.....	1.65%
<hr/>		<hr/>	
100.00%		100.00%	

The production of milk powder becomes a process for the changing of a liquid to a solid. Drying milk has always been possible in a crude way but only within the last fifteen or twenty years has it been possible to produce dry milk by processes that made the product a commercial proposition.

The production of milk in a dry stable form has been given serious consideration for years because there is nothing quite so perishable or unstable as liquid milk. There is no food that can carry disease and impurities so well and do such endless harm as liquid milk. In the early days of experimenting to obtain a commercial product various methods were used to produce a dry milk that would be a satisfactory commercial product. It, of course, was always common knowledge that heating milk to a high temperature and thereby removing the moisture by evaporation would leave a solid substance which of course was the solids of the liquid milk.

The first practical method of drying milk in a commercial way was done by what is commonly known as the "roller process." Patents for this process were taken out and milk powder is still being produced in all countries by this process. The original method of drying milk by this process was to allow fresh liquid milk to pour in streams upon the surface of steel rollers revolving in opposite directions and against each other. These rollers were made hollow forming chambers into which live steam was introduced. The heat of the steam transmitted through the metal surface of the rollers converted the moisture of the milk into steam which passed off in the form of vapor. As the rollers operating in pairs in opposite direction could be adjusted so that they would allow a thin film of milk to pass between them, a perfectly even surface or film of milk would be left on the revolving cylinders. Against the upper surface of each roller, a knife was set to scrape or cut from the surface of the roller the film of milk solids that would be left after the moisture had evaporated during the time taken for the milk film to pass around the revolving surface of the rollers. The product produced was a fair quality of milk solids or milk powder.

The process in recent years has been made more practical by having the milk partly concentrated or condensed before it passes to the roller machine for the final drying. This precondensing process cut down the time and cost of drying on the rollers to a very large extent and made the whole process a much more practical and important one from a commercial point of view. The milk powder was made more satisfactory for ordinary commercial uses by having the powder put through a sifting machine that divided up the sheets of milk solids into a uniform product.

The drying of milk in Canada was first done commercially in November, 1903, by Mr. B. A. Gould. A cheese factory was converted into a crude milk drying factory and these roller process machines were used exclusively for producing this milk powder. From 1903 to 1909 those interested in the production of milk powder by this crude and unsatisfactory method of drying milk were using every resource to develop the process and produce a product that would be more satisfactory for general commercial uses. Milk powder produced by the roller process is not entirely soluble in water. The extreme heat to which the milk is subjected in this process changes the physical

and chemical composition of the ingredients of milk to such an extent that the milk solids or milk powder so produced cannot be restored to their original physical and chemical composition as in fresh liquid milk.

It was known that if milk could be dried and be in a condition from which it could be changed into the original fresh liquid milk the commercial use of milk powder would be increased many times. As a matter of fact it was appreciated that milk powder that could be restored to its original condition could be used for all purposes to replace fresh liquid milk. The Merrell-Soule Company of Syracuse, N.Y., U.S.A., and Trufood, Limited, of England, worked on this problem previous to 1909 with a view to developing machinery and equipment that would produce milk powder that would be entirely soluble in water.

Certain conditions existing in handling the milk by the roller process had to be overcome in order to produce a soluble milk powder and also milk powder which when restored to liquid would taste and be like the fresh liquid milk from which it was produced. The first thing was to work out a process for evaporating the moisture from milk without changing the chemical composition of the milk solids. This meant handling the milk at a temperature that would not affect the milk solids as they are affected by the old roller process. As evaporation of moisture takes place when moisture comes in contact with dry air, this theory was developed with milk to a point where it was possible to eliminate the moisture and leave a soluble milk powder. This result was obtained best by spraying or atomizing the liquid milk into dry air. This subjected the moisture of the liquid milk to the largest amount of evaporating surface with the result that it was found that the milk solids and the moisture could be so separated as to leave a dry product. Experiments were carried on with this theory as the basis for work to a point where in 1909 a complete milk drying equipment was developed and machinery and equipment installed to produce a soluble milk powder to dry milk by this spray process. Based on this point, the production of milk powder for all milk uses will now be described from the handling of the milk from the farm to the user.

IMPORTANCE OF SPRAY PROCESS.

Although the roller process milk powder, has regular uses, the milk powder proposition really rests upon the spray process which is now employed in all countries for drying milk and producing a product that is absolutely soluble in water and that is like the original fresh liquid milk when it is restored to the liquid state again.

PRACTICAL MILK HANDLING.

The farms producing milk are covered by regular inspection employed for the express purpose of inspecting milk production. This means enforcing standards for the care of cattle, the care of stables, the care of barn yards, the care of milk utensils and of course the care of milk itself.

As soon as the milk is delivered it is pasteurized by the best known method which is commonly described as the "holding method." This means holding the milk at a certain temperature for a certain length of time. The temperature and the length of time of holding have been a source of discussion. Lectures and arguments to determine which are the best temperatures and lengths of time to properly pasteurize milk. The usual method is to hold milk at approximately 155 degrees for 20 to 30 minutes.

As soon as the milk is pasteurized it is carried through sanitary piping to condensing machines. This piece of apparatus is known as the vacuum pan. It is a large copper tank that will hold from 1,200 to 1,500 gallons of milk, steam jacketed, fitted with airtight condensing chamber and vacuum pump. The milk is taken into this pan, the pan is closed and made airtight and the vacuum is produced by the vacuum pump

through the condensing chamber from the top of the vacuum pan. The object of putting the milk through this part of the process is to remove or evaporate a part of the water of the milk. The object in doing this part of the process under vacuum is to reduce the volume of the milk at temperatures that will in no way affect the milk solids either chemically or physically. If the evaporating process were carried on open to the atmosphere, temperatures higher than boiling point would have to be used and the chemical composition of the milk solids would be changed and injured and the product made insoluble which of course cannot be allowed to occur when milk powder is required to be absolutely soluble in water. The temperature employed in reducing in the vacuum pan is approximately 125 degrees to 130 degrees. This vacuum pan method of condensing milk is called the "batch" pan method. This means a given quantity of milk is put in the pan, started operating and the process of condensing finished before any milk is removed.

As this method of batch condensing has never been considered perfect because the milk is subjected to this part of the process for so long a time, various apparatus have been used in experiments to condense or evaporate part of the water from the milk by a continuous process. There is no doubt that reducing milk by a continuous vacuum process will ultimately be developed and will produce a better product. Any effect that is made upon liquid milk in this part of the process of reducing the milk to powder form shows in the finished product.

Perhaps it would be well to make it clear why in the milk powder business it is necessary or advisable to partly concentrate milk before it is made into milk powder when it is possible to produce milk powder without concentrating the milk first. One of the reasons is that it cuts down the cost of production because it is cheaper to remove the amount of moisture from the milk which is taken from it in the vacuum pan part of the process than to take all of the water from the milk in the milk drying part of the process. It would not be commercially profitable, even though possible, to dry milk without first condensing it because of this precondensing operation, cutting down the cost of production. Another point is that a superior milk powder is obtained by first condensing the milk or concentrating it and then drying it in the final part of the process. This point is not so easy to explain but could be demonstrated.

Do not confuse this condensing part of a milk drying process with the common idea of condensed milk. Condensed milk is produced in a similar way but the milk is put through a processing which is necessary when the milk is not to be carried into the dry state but must be preserved in semi-liquid form as is condensed milk and evaporated milk. The term "condensed" as used in the milk powder business is simply used synonymously with "concentrated" or reduced in "volume."

Turning to the more important and final stage of producing milk powder, the milk as it comes from the condensing pan, it is then delivered in sanitary pipes to what is called in the business the spray box. The central object in making milk powder which is to be accomplished is the evaporation or removal of water of liquid milk leaving the dry milk solids in a perfectly soluble form.

EVAPORATION.

To produce evaporation, air must be used and to increase the speed of evaporation dry air must be used as well as heated air. The air must be kept moving. Through what is called the dry box passes continually a circulation of filtered, heated, dry air. Into this circulation of air the precondensed milk above described is atomized. The equipment used to accomplish this atomizing condition is of course important but not essential to describe. Suffice it to say that the instant the dry heated air comes in contact with the thin atomized film of milk the moisture of the milk is taken up or

evaporated by the air and the milk solids fall by gravity like flour or snow or pulverized sugar to the bottom of the drying box or unit.

In order to have economy of operation in milk powder plants several drying boxes or drying units are arranged so that the process can go on continuously throughout the working day even though one or more units may not be working due to break down or other obstacles.

In order to have filtered heated dry air circulating through the drying units it is necessary to have large boiler capacity for steam production, steam heated coils for air heating, mechanical filters for filtering air and fans for circulating the air. Each drying unit is equipped with collecting and air-filtering apparatus that gathers in the powder and saves it from passing out of drying unit into the outgoing air conductor. This part of the process is naturally one that is being developed and on which experiments are being carried on continuously in order to obtain greater drying efficiency and at the same time save any possible loss of milk powder through its passing out with the circulating air.

The final part of the process is simply that of collecting the dry milk solids from the drying units in sanitary cans and packing this milk powder in sanitary containers provided for the purpose and containers adapted to holding powder for particular uses.

In view of the prejudice against milk in any other form but the liquid, it is well to point out how absolutely pure and unadulterated milk powder is. Chemically it is pure. That is to say, there are no preservatives, chemicals or adulterants of any kind used in the process of making it. (Vide Dr. A. McGill, Inland Revenue Bulletin No. 257, the analysis of milk products).

From the bacteriological side of milk powder a very interesting set of conditions exist. As the process of pasteurization of the milk before it is condensed or dried eliminates all pathogenic bacteria, naturally the dry milk powder is almost absolutely free from bacteria. In other words it is pure from the point of view of disease producing bacteria. As bacteria will not multiply in the absence of moisture the milk powder will keep indefinitely so far as the multiplication of bacteria and the souring of the product is concerned. If it comes in contact with moisture the same effect will result as results when liquid milk turns sour. This is simply the rapid multiplication of the lactic acid bacteria and other bacteria common to milk.

Milk powder will keep indefinitely so far as the bacterial impurities are concerned as long as it is in the dry state. Milk powder that has the fat in it or in other words whole milk powder will not keep indefinitely. It will not keep indefinitely because of the butterfat in it becoming rancid in time when the milk powder is kept under ordinary storage conditions. Under such conditions in the course of a few weeks the acids that make up the butterfat begin to oxydize and the butyric acid element of the butterfat breaks down and causes rancidity. This is what occurs when ordinary table butter becomes rancid. It is simply a chemical change that occurs. Cold storage delays the breaking down of the butyric acid part of the butterfat in milk powder so that milk powder kept in cold storage will keep months in perfect condition so far as taste is concerned before it starts to go off flavor.

Technically speaking, raw milk contains enzymes which are known to exist in milk which have never yet been actually separated from milk and their character known. The matter is covered by simply the expression that raw milk has the "life" of the milk preserved. Pasteurization does not affect the "life" or the enzymes of the milk. Sterilization destroys the enzymes. On account of the absence of the enzymes in infant foods and in boiled or condensed milk it is always explained that orange juice should be used. This gives the enzyme life absent in boiled or sterilized milk food. This process of drying milk in no way affects the enzymes of the milk. In other words milk powder is in a perfect milk condition so far as this essential quality is concerned. For infant feeding this is one of the essential qualities in a food.

By making the Leffman test this point can be demonstrated as described above. There is no more convincing demonstration that can be made to a medical or technical man than this test upon milk powder because few persons realize that it is possible to produce milk powder and have the enzymes preserved when it is ordinarily understood that in the production of any milk food the enzymes are the first element to be destroyed under ordinary conditions. Milk powder as produced by the spray process is therefore most extraordinary from this point of view.

Following this simple test it might be well to make a slight comparison of milk powder with the common condensed milk and evaporated milk because these two products are somewhat akin to milk powder and yet far removed from it.

Condensed milk is produced by removing a part of the moisture from the milk, then adding sugar to it as a preservative.

Evaporated milk is simply unsweetened condensed milk processed at high temperature to preserve it.

Naturally because of the process these two products have to go through the enzymes are destroyed and consequently condensed milk is not a satisfactory food for infant feeding when this one point is considered. In view of the heat to which these two products are subjected in the process of manufacture the chemical condition of the milk solids is changed. The casein of the milk is made insoluble. The milk albumen is coagulated and becomes insoluble. The milk sugar or lactose of the milk is broken down and caramelized and the ash, carbonates and salts of the milk are changed chemically. These changes make it impossible to restore either sweetened condensed milk or evaporated milk to their original condition.

There are two or three other points in connection with the handling of the milk that should be covered in this connection. Whole milk to be made into whole milk powder is precondensed before spraying in the ratio of $2\frac{1}{2}$ per cent. to 1 per cent. Separated milk before spraying is condensed in the ratio of $4\frac{1}{2}$ per cent. to 1 per cent. Naturally whole milk cannot be precondensed as low as separated milk on account of the fat content in whole milk.

The solids of milk in the form of milk powder made by spray process are absolutely soluble in cold water. When once dissolved the solids remain in solution and are the same as in the fresh liquid milk from which the milk powder was produced. This perfect solubility of milk powder is the one characteristic that makes it possible to use milk powder for every purpose for which fresh liquid milk can be used.

Since the process was perfected for producing soluble milk powder it has been the aim to produce milk powder that will have no process flavor or flavor caused by the handling of the milk in the process. The product as now manufactured for household use can hardly be distinguished from fresh liquid milk, and it will not be long before the flavor of the milk powder is so perfect that it cannot be distinguished from fresh liquid milk.

COST OF CLEANING.

There is another point in connection with the handling of milk and cream. Needless to say in order to produce a high grade milk powder with a clean flavor the sanitary conditions of milk powder plants must be perfect. More than 50 per cent. of labor expense and time covers washing and cleaning.

Milk that is brought from the morning milking at 6 o'clock or 7 o'clock in the morning is pasteurized, precondensed and dried into milk powder within a few hours after milking. Actually speaking a given quantity of milk is not in the process of drying more than 30 minutes from the time it is received until it is in the milk powder form, when the precondensing is done by the continuous process.

THE USES OF MILK POWDER

EACH PRODUCT IN DETAIL.

Whole milk powder has all of the fat of the milk in it. Separated milk powder has very little fat in it and cream powder has approximately 72 per cent. of fat in it. Modified milk powder and sweet whey powder are simply obtained by modifying the proportions of the different dry ingredients of milk to produce the desired food for the particular purpose for which it is intended.

Whole milk powder is produced for use as the milk in milk chocolate in confectionery and to a limited extent in biscuit manufacturing and in creamery and dairy work. Until a satisfactory milk powder was produced liquid milk or condensed milk had to be employed. The chief trouble with these two forms of milk is the presence of water. The confectioner and baker spends more time in his work getting rid of water by cooking or baking than he does at anything else. Give him his milk without water and you have solved his most serious problem if he is a milk user and if his product cannot be produced without milk.

WHOLEMILK POWDER.

The straight whole milk without the water produces the original liquid whole milk again when it is mixed in the proportions of 7 lbs. of water to 1 lb. whole milk powder.

ROLLER PROCESS.

Referring to the roller process milk powder, practically the only use for the roller process powder, which is a whole milk powder that is not soluble, is for milk chocolate manufacturing. Milk chocolate production does not require a milk that has to be absolutely soluble in water. It is used with cocoa butter and sugar in machines that grind all the ingredients together which produce the finished milk chocolate.

SPRAY PROCESS VS. ROLLER PROCESS.

It is natural to question why some use the soluble whole milk powder, and some the roller process whole milk powder. This brings up a technical point which can be dealt with here perhaps to best advantage. In spraying or atomizing whole milk in the spray process used to produce soluble milk powder the butterfat particles of the milk that goes through the roller process is not atomized so that the butterfat in the resulting milk powder is in large bits or globules. To put it roughly the butterfat is more in "chunks" although of course only in very small pieces. As the production of milk chocolate is a question of grinding and rubbing different ingredients together it has been found when spray milk powder is used that it takes more cocoa butter to work out the butterfat from the milk powder because the fat particles are so finely divided. The operation, therefore, of making milk chocolate with spray milk powder is a longer operation and more cocoa butter is required to get the desired result. Roller process milk powder with the larger fat globules incorporates more readily with the other milk chocolate ingredients requiring a shorter operation and less cocoa butter. The finished milk chocolate made with sprayed milk powder is a finer grained product because all of the solids of the milk completely dissolve in the process of making milk chocolate. As the milk solids in the roller process powder will not dissolve completely there is, therefore, a certain roughness to the texture of milk chocolate made with roller process powder. Those desiring to produce the finest quality of milk chocolate prefer the spray process milk powder to the roller process powder for the reasons given

SEPARATED MILK POWDER.

The separated milk powder that has little or no fat in it has a far wider field of uses. Its chief use is in baking and in biscuit manufacturing. Some of the reasons for using it in place of fresh liquid milk in this work are the same so far as having milk in a dry state is concerned. Of course the uses are different to a large extent because for many purposes milk powder without the fat is preferable to milk powder with the fat content. For instance the biscuit manufacturer produces one-hundred different kinds of goods. Each kind has its particular formula. Each kind has its particular amount of milk and fat in the formula. As the fat or shortening element in a baking formula is the one that is varied perhaps more than any other, the biscuit manufacturer and the baker prefer to have their milk without the fat so that they can vary their fat ingredient by using in one article the highest grade butter, in another a cheaper dairy butter and in still another some form of shortening or hard fat that is common to the business. Separated milk powder, therefore, supplies the milk part of a formula for all biscuit and baking work.

Since the quality and flavor of separated milk powder, have been improved during the last two or three years its use in ice cream manufacturing and in general dairy and creamery work has increased so that today separated milk powder is almost indispensable to the ice cream manufacturer and to the creamery. For ice cream it supplies the milk solids of the ice cream. So often ice cream manufacturers use ice cream powders and fillers which are even more expensive than the pure milk solids. In other words separated milk powder adds to the food value of ice cream and at the same time offers other advantages in ice cream making. It is possible by using fresh unsalted creamery butter and water and separated milk powder to produce liquid cream which can be used for all purposes for which liquid cream is used. Thus supplying a ready means to hand for the ice cream manufacturer when he cannot get his usual supply of liquid cream. Separated milk powder is used in this way by dissolving it and combining it with the melted butter and emulsifying these ingredients or putting them through what is called a homogenizer which is simply a machine for thoroughly incorporating these products to make a smooth finished cream. Another important use for separated milk powder is in making culture for culturing cream for butter making. As separated milk powder is free from bacteria a solution of it is a clean medium in which to culture the lactic acid bacteria for starter or butter making purposes. As buttermilk, after the butter has been removed, is simply sour separated milk it can be seen that it is also possible to produce the same product which we call buttermilk by culturing a liquid mixture in this way.

CREAM POWDER.

Coming to the cream powder, all that can be said about the use of this, is that when it is dissolved in the amount of water that was originally taken from it, it may be used for all purposes for which sweet cream may be used. Of course it is more expensive to produce than the regular cream. For domestic use this cream powder will not be common because the butterfat in it will not keep indefinitely and consequently it cannot become a grocery store proposition in the same manner as a domestic milk powder would have to be and is. Cream powder is, therefore, used almost exclusively by ice cream manufacturers during the shortage of cream in the summer and in fine caramel work. It is only recently that it was possible to produce cream powder that could be dissolved in water again and be the same as fresh liquid cream from which it was produced.

BABY FOODS.

Modified milk powder and sweet whey powder are products which have been manufactured since the spray process was first introduced. By making sweet whey in liquid form, then drying it by the regular spray process, the pure dry sweet whey powder is obtained. Sweet whey is chiefly albumen and milk sugar and on that account is an exceedingly rare and valuable food for serious cases of stomach trouble in case of infants and invalids.

Being able to produce whey powder makes it possible to take ordinary whole milk powder produced from especially selected high-grade milk, dry it by the spray process and combine the whole milk powder so made with the sweet whey powder giving a modified milk powder that has the milk solids in proportions close to those in the ordinary mother's milk. In other words this product comes nearest to the natural milk for baby feeding. It might be said that modified milk powder is the only all milk absolutely soluble baby-food produced. The nearest product to this is an all-milk food that does not contain any malt or cereal, is a dry milk baby food which is produced today in England by the chi roller process, described earlier in this paper. Naturally a baby food dried by such a process is not anything like as superior for baby feeding as a whole-milk soluble milk powder. All other infant foods or patent baby foods are compositions of cereals, malt, milk powder, etc.

POWDERMILK HOUSEHOLD USE.

There is more body-building food in a quart of skim milk than in a quart of milk with the fat in it. Referring to the analyses, difference between liquid whole milk and skim milk or separated milk, is that the separated milk powder contains little or no fat and that the whole milk powder contains over 28 per cent. of fat. One is produced from the whole liquid milk without any fat being removed and the other is produced by drying skim milk or separated milk. It is common for the house wife and the user of milk to shy at the words "skimmed milk," simply because it is the common impression that when fat is removed from the milk in the form of cream all of the good is taken away. It is not true to say that all of the good of the milk is gone from the milk when the fat is removed, but referring to the fat as the most valuable part of the milk is a different matter.

Fat in the form of butter has a market value so that the amount of fat taken from 100 lbs. of milk would have a certain value. Referring to the analysis again it will be seen that in a quart of milk there is a little less than $1\frac{1}{2}$ ounces of butterfat. Far the largest part of the money value of liquid milk is in the butterfat. The other part is the solids of the milk. Yet for body building food this less valuable part from the cost point of view has more value than the fat. As butterfat and meat fats are common to every home, it can be realized why food experts state that skim milk is better food than whole milk. The only difference between the two is that a quart of whole milk has $1\frac{1}{2}$ ounces of fat in it and a quart of skim milk has not this fat in it but has the other milk solids in a slightly larger proportion. Comparing milk powder which is the solids of separated milk with whole milk for household use, therefore, you must consider the food value of milk powder as compared with liquid milk. Looking at the analysis of whole milk powder and separated milk powder it will be seen that nearly one-third of whole milk powder is butterfat. In the separated milk powder this large proportion of butterfat is replaced by the increased proportions of the other ingredients of the milk, albumen, casein, milk sugar and the salts of the milk which are the body building food value of the milk. Fat is the energy or heat producing element and this element is obtained regularly in other forms such as in butter, meat fats, lard, shortening and cereals. The use of milk powder, therefore, gives a 100 per cent. body-building food.

Milk for home use is consumed as a food and therefore milk powder must be considered from the point of view of food value.

MILK PROBLEM.

It supplies milk in a form that can be used anywhere and everywhere in place of fresh liquid milk. Separated milk powder is not skimmed milk. Skimmed milk, as the analysis shows, is 91 per cent water. Separated milk powder is the 9 per cent. solids of skim milk or is the 100 per cent. food value of skim milk. Separated milk powder is therefore, the most concentrated food that can be bought and contains more body-building food value than any other food at the price.

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YEAR**

- 1919—CORMAN, H. E.
329 College St., Toronto.
- 1919—FORMAN, JOHN H.
Dept. of Applied Chem.,
University of Toronto
- 1919—FETZER, W. RAY.
Room 14, Mining Bldg.,
University of Toronto.
- 1919—FULMER, E. T.
Chemical Building,
University of Toronto.
- 1919—FUNNELL, W. S.
Chemical Building,
University of Toronto.
- 1919—HAMBLETON, &
743 Brock Ave., Toronto
- 1919—HOTE, W. W.
Glidden Varnish Co., Ltd.
380 Wallace Ave.,
Toronto.
- 1919—MARSHALL, ALEX.
Canadian Manufactur-
ers Association, Toronto
- 1919—MARSHALL, A. L.
Chemical Bldg.,
University of Toronto.
- 1919—MASON, J. H.
182 Richmond St., W.
Toronto.
- 1919—MORGAN, J. W.
24 Barton Ave., Toronto.
- 1919—MORGAN, J. W.
24 Barton Ave., Toronto.
- 1919—KNIGHT, G. W.
co. The Wm. Davies Co.
Ltd., 521 Front St. East,
Toronto.
- 1919—McKAY, P. G.
Can. Laboratory Supt
plies, Ltd., 615 Yonge St
Toronto.
- 1919—RUDDY, J.
co. Canada Starch Co.,
Ltd., 45 Front St. East,
Toronto.
- 1919—SIMMETT, C.
Harris Abattoir Co., Ltd
West Toronto.
- 1919—SMITH, M. E.
Chemical Building,
University of Toronto.
- 1919—SWINNERTON, A. A.
31 Avenue Rd., Toronto.
- 1919—THURLOW, C. F.
co. Wm. Davies Co., Ltd,
521 Front St. East,
Toronto.
- 1919—WILSON, J. H.
co. Consolidated Lab.
Equipment Co.,
615 Yonge St., Toronto

**ENTRY
YEAR**

- 1919—WILSON, J. S.
37 Balmuto St.
Toronto.
- 1919—STANYON, C. H.
31 Brock Ave., Toronto.
- 1919—STANYON, L. L.
31 Brock Ave., Toronto.
- 1919—SHELDON,
Sternwear Tire Co.,
Toronto
- 1919—WILLS, W. H.
co. The Wm. Davies Co.,
Ltd., 521 Front St. East
Toronto.

ONTARIO MEMBERS

- 1919—BARLOW, H. C.
co. Delora Smelting &
Refining Co.,
Delora, Ont
- 1919—BEVERIDGE, J. B.
co. Dryden Timber &
Power Co., Ltd.,
Dryden, Ont
- 1919—BOEHMER, H. C.
35 College Street,
Kitchener, Ont
- 1919—BREITHAUPT, J. E.
co. Breithaupt Leather
Co., Ltd.,
Kitchener, Ont
- 1902—BROWN, A. H.
Kent St., London, Ont
- 1919—BROWN, L.R.
55 Summit Ave.,
Sault Ste. Marie, Ont
- 1918—BURR, C. G.
71 Cartwright St.,
London, Ont
- 1918—CADENHEAD, A. F.
Queens University
Kingston, Ontario
- 1919—CARMICHAEL, C. M
co. Electro Metals Ltd.
Welland, Ont
- 1919—CHADSEY, S. B.
co. Massey-Harris Co.,
Ltd., Brantford, Ont.
- 1919—CHADWICK, W. W.
186 Wellington St. N.,
Hamilton, Ont.
- 1919—CORLISS, C. V.
co. Mond Nickel Co.
Coniston, Ont
- 1919—COWELL, MAJOR, P.
co. Thompson & McKin-
non, London, Ont
- 1919—CROWN, H. A.
Canadian Glue Co.,
Brantford, Ont.
- 1919—DRUMMOND, G. D.
co. Canada Iron Cor-
poration Ltd.,
Midland, Ont
- 1919—FAUST, T. A.
co. Yccum Faust Ltd.,
London, Ont.

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| <p>ENTRY
YEAR
1919—GILBERT, B. E.
R. R. No. 4, Paris, Ont.</p> <p>1919—GIRVIN, H. G.
141 Grant Ave.
Hamilton, Ont.</p> <p>1919—GRAY, W. T.
Port Credit, Ont</p> <p>1919—HARCOURT, PROF. R
Ont. Agricultural Col-
lege, Guelph, Ont.</p> <p>1919—HENDERSON, E. G.
co. Canadian Salt Co.,
Windsor, Ont</p> <p>1919—JACOBS, L.L.
co. Algoma Steel Cor-
poration,
Sault Ste. Marie, Ont.</p> <p>1919—JOHN, DAVID
Haileybury, Ont</p> <p>1919—JONES, D. R.
co. Wood Products Co.,
Donald, Ont</p> <p>1919—KAUFMANN, W. P.
co. Malt Products Co.,
Guelph, Ont</p> <p>1919—LAMBLE, E. C.
co. International Molyb-
denum Co., Ltd.,
Orillia, Ont</p> <p>1919—MacDONALD, G. G.
Box 113, Parry Sound,
Ont</p> <p>1919—MacGREGOR, S. E.
Delora, Ont</p> <p>1919—MANSELL, R. B.
258 McGregor Ave.,
Sault Ste. Marie, Ont.</p> <p>1919—McINTYRE, DR. A. E
Lindsay Arsenal,
Lindsay, Ont</p> <p>1919—MARLATT, W. T.
Oakville, Ont</p> <p>1919—MARRIN, I. P.
Delora, Ontario.</p> <p>1919—MOORE, E. P.
34 Jackson St. East,
Hamilton, Ont.</p> <p>1919—MOSBAUGH, F. R.
co. Anglo Canadian Tan-
ning Co.,
Huntsville, Ontario.</p> <p>1919—ORTVED, C. N.
co. Hiram Walker &
Sons, Ltd.,
Walkerville, Ont.</p> <p>1911 PHILLIPS, LT. COL. WE
co. W. C. Phillips, Fron-
tenac Club, Kingston</p> <p>1918—PONTON, G. M.
Belleville, Ont.</p> <p>1919—SCHMUCK, JAS.
International Harvester
Co., Hamilton Ont</p> | <p>ENTRY
YEAR
1919—SHANNON, H. E.
Delora, Ont.</p> <p>1919—STEPHINSON, J.
United Gas & Fuse Co.,
Hamilton, Ont</p> <p>1919—STERNE, PROF. E. T
Kingston, Ont</p> <p>1919—STUART, F. A.
534 Waterloo St.,
London, Ont.</p> <p>1919—STUART, G. G.
co. Stuart Bros.,
Niagara Falls, Ont.</p> <p>1919—THORNE, C. B.
co. Riordon Paper Co.,
Hawkesbury, Ont.</p> <p>1919—TOBEY, C. H.
Burks Falls, Ont.</p> <p>1919—WHEATLEY, A.C.
co. Parry Sound Iron Co
Parry Sound, Ont.</p> <p>1919—WOOD, DR. ERNEST
co. Dominion Tire Co.,
Kitchener, Ont.</p> | <p>ENTRY
YEAR
1913—CANTELO, R. C.
Fuel Testing Plant,
Booth St., Ottawa, Ont</p> <p>1918—COOK, S. J.
317 Queen Street,
Ottawa, Ont.</p> <p>1918—COLE, D. S.,
Iroquois Falls, Ont.</p> <p>1908—COLLIER, F. C.
317 Queen Street,
Ottawa, Ont.</p> <p>1918—CONNOR, M. F.
35 Second Ave.
Ottawa, Ont.</p> <p>1907—EMSLIE, B. L.
Experimental Farm,
Ottawa, Ont.</p> <p>1918—GILMORE, ROSS E.
585 O'Connor Street,
Ottawa, Ont.</p> <p>1918—HAANEL, DR. E.
Mines Branch Sussex St
Ottawa, Ont.</p> <p>1913—HAFF, MAX M.,
70 Clarey Ave.,
Ottawa, Ont.</p> <p>1919—HAMBLY, F. J.
Buckingham, Que.</p> |
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| OTTAWA DISTRICT
MEMBERS | | |
| <p>1908—BABINGTON, F. W.
41 Lyon Street,
Ottawa, Ont.</p> <p>1900—BELL, H. P.
University Club,
Ottawa, Ont</p> <p>1918—KITTO, V.
317 Queen Street,
Ottawa, Ont.</p> <p>1904—McGILL, DR. A.
317 Queen Street,
Ottawa, Ont.</p> <p>1919—McANALLY,
Canada Cement Co.,
Hull, Que.</p> <p>1918—MacRAE, A. E.
Patent Office,
Ottawa, Ont.</p> <p>1919—PIRRIE, N. W.I.M.B.
Ottawa, Ont.</p> <p>1890—SHUTT, DR. F. T.
Experimental Farm,
Ottawa, Ont.</p> <p>1919—SMITH, E. A.,
Experimental Farm,
Ottawa, Ont.</p> <p>1910—THOMAS, O. J. D.
co. E. B. Eddy Co.,
Hull, Que.</p> <p>1905—WHITE, WM.
124 Bayswater Ave.,
Ottawa, Ont.</p> | <p>ASSOCIATES</p> <p>1919—BRADLEY, S. W.
381 Somerset Street,
Ottawa, Ont.</p> <p>1919—BROWNE, L. A.
Experimental Farm
Ottawa, Ont</p> <p>1919—BARIDON, FREDKW
Mines Branch, Sussex
Street, Ottawa, Ont.</p> <p>1919—CHENE, JEAN D.
701 Booth Bldg.,
Hull, Que</p> <p>1919—CLARK, K.A.
Mines Branch,
Sussex St., Ottawa, Ont.</p> <p>1919—DE BRYUNE, A
Aylmer East., Que.</p> <p>1919—ELLSWORTH, H. V.,
Ph.D., 227 Sparks St.,
Ottawa, Ont.</p> <p>1919—GRATTAN, GEO. E.
317 Queen Street,
Ottawa, Ont.</p> <p>1919—KAUFMAN, M. A
71 Alonzo Street,
Hull, Que.</p> <p>1915—HOWARD, DR. G. S.
Carleton Place, Ont.</p> <p>1919—KLOCK, ALONZO
559 Packdale Ave.
Ottawa, Ont.</p> | |

**ENTRY
YEAR**

- 1919—LEVERIN, H. A.
Mines Branch,
Sussex Street,
Ottawa, Ont.
- 1919—MORAN, JAMES,
Fuel Testing Plant,
Booth St., Ottawa, Ont.
- 1919—NICHOLLS, J. H. H.,
Fuel Testing Plant,
Booth St., Ottawa, Ont.
- 1919—PYE, W. A.
13 Elgin Street,
Ottawa, Ont.
- 1919—ROWAT, R. M.
163 Flora Street,
Ottawa, Ont.
- 1919—TAPLEY, RALPH A.
110 Nepean Street,
Ottawa, Ont.
- 1919—VALIN, AIME
317 Queen Street,
Ottawa, Ont.
- 1919—VIENS, EPHRAM
Laboratory for Testing
Materials, Public Works
Dept., Ottawa, Ont.
- 1919—WRIGHT, L. E.
Experimental Farm,
Ottawa, Ont.
- 1919—WRIGHT, MISS S. E.
317 Queen Street,
Ottawa, Ont.

**MONTREAL DISTRICT
QUEBEC & MARITIME**

- 1916—ALLEN, W. R.
co. Watson, Jack & Co.
Montreal, Que.
- 1913—BANKS, A. J.
co. Ogilvie Flour Mills
Co., Montreal, Que.
- 1907—BARDORF, CHAS. F.
co. St. Lawrence Sugar
Reyning Co.,
Maisonneuve, Que.
- 1919—BARIL, GEO.
Laval University,
Montreal, Que
- 1915—BATES, J. S.,
co Price Bros. & Co.
Kenogami, P.Q.
- 1919—BEAUDRY, J.
275 Outsement Ave.,
Montreal, Que
- 1916—BELL, J. B.
4489 Sherbroowe St.,
Montreal, Que.
- 1909—BENSON, GEO. F.
164 St. James Street,
Montreal, Que.
- 1915—BETTESWORTH, A. E
394 St. Paul Street,
- O.M.—BEVERIDGE, JAS.
17 St. Therese Street,
Montreal, Que.

**ENTRY
YEAR**

- 1915—BLAKE, A. F.,
Atlantic Sugar Refiner-
ies, Ltd., St. John, N.B.
- 1918—BOURGOIN, PROF. L
228 St. Dennis St.
Montreal, Que.
- 1917—BROWN, N. B.
co. Shawinigan Electro
Metals Co.,
Shawinigan Falls, Que.
- 1917—CAMPBELL, W. B.
275 Addington Ave.,
Montreal, Que.
- 1886—CARTER, W. C., F.I.C.
co. Dominion Iron &
Steel Co.,
Sydney, C.B.
- 1909—CLARK, H. A.,
83 Amherst St.,
Montreal, Que.
- 1910—CORNELL, FRED. E
16 Place Royale,
Montreal, Que.
- 1919—CROWTHER, C. W. W
Box 91, Shawinigan Falls
Que.
- 1919—CUSHING, E. A.
Wanagamack Pulp &
Paper Co., Three
Rivers, P.Q.
- 1902—DeCEW, J. A.
903 McGill Bldg.,
Montreal, Que.
- 1903—DONALD, DR. J. T.
318 Lagauchetiere St. W
Montreal, Que.
- 1914—DONALD, J. R.
318 Lagauchetiere St.,
Montreal, P.Q.
- 1911—DOUGALL, J. B.
co Canada Sugar Refin-
ing Co., Montreal, Que.
- 1911—DRACKETT, H. R.
Westmount, Que.
- 1910—EASTLAK, W. H.,
co British Munitions
Co., Que.
- 1909—EDWARDS, G. M.
241 Pine Ave. W.,
Montreal, Que.
- 1909—EVANS, PROF. N. N.
McGill University,
Montreal, Que.
- 1911—FAREY, F. O.,
905 McGill St.,
Montreal, Que.
- 1902—FERGUSON, D. M.
Acadia Sugar Ref. Co.
Halifax, N.S.
- 1907—FORWARD, CHAS. C.
50 Bedford Row,
Halifax, N.S.

**ENTRY
YEAR**

- 1915—FROST, C. E.,
259 Metcalf Ave.,
Westmount, Que.
- 1918—GRAGEROFF, I.
214 Bishop Street,
Montreal, Que.
- 1907—HAMBLY, FRED J.
co. Elec. Reduction Co
Buckingham, Que.
- 1901—HANNA, C. E.,
Montreal, Que.
- 1916—HARLOW, L. C.
Agricultural College,
Truro, N.S.
- 1918—HAYDEN, T. E.
225 Lemoine St.,
Montreal, Que.
- 1903—HAZEN, C. R., M.Sc.,
P.O. Box 1086,
Montreal, Que.
- 1898—HERSEY, DR. M. L.
P.O. Box 1086,
Montreal, Que.
- 1919—HOLLAND, N.
Holland Varnish Co.,
Montreal, Que
- 1892—HOLLAND, P. H.,
546 Sherbrooke St.,
Montreal, Que.
- 1904—HOPEWELL, FRED.
59 William St.,
Montreal, Que.
- 1918—HORNER, F. W.
40 St. Urbain St.,
Montreal, Que.
- 1911—JAMIESON, R. H.
264 St. Patrick St.,
Montreal, Que.
- 1896—JOB, ROBT.,
649 Roslyn Ave.,
Westmount, Que.
- 1895—JOHNSON, JESSE F.
P.O. Box 94,
St. Anne de Bellevue, Qu
- 1915—KECHLAND, C. G.,
524 St. Ambrose St.,
Montreal, Que.
- 1915—LAFLANTE-COURVILLE, E. H.
Laval Dental School,
Montreal, Que.
- 1913—LLOYD, PROF. F. E.
McGill University,
Montreal, Que.
- 1916—LODGE, W. C.,
603 Canadian Express
Bldg., Montreal, Que.
- 1916—LYMAN, ARTHUR,
co. Lymans Limited,
344 St. Paul Street,
Montreal, Que.
- 1906—LYONS, R. H.,
co. Can. Explosives, Ltd
Beloeil Station, Que.

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| <p>ENTRY
YEAR
1919—McFEE, M. C. C.
164 Hutchinson St.,
Montreal, Que.</p> <p>1913—MacINTOSH, GEO.
516 St. Ambroise St.,
Montreal, Que.</p> <p>1918—MACKAY, PROF.
Dalhousie University,
Halifax, N.S.</p> <p>1913—MacKINNON, E. A.,
324 St. Paul Street,
Montreal, Que.</p> <p>1919—MACLEAN, Dr. A. R. M.
24 Chomedey St.,
Montreal, Que.</p> <p>1913—McCRADY, M. H.,
59 Notre Dame, E.
Montreal</p> <p>1916—McINTYRE, G. D.
720 Trnsprttn Bldg.,
Montreal, Que.</p> <p>1914—McTAVISH, D. D.
626 Roslyn Ave.,
Westmount, Que.</p> <p>1919—McLEOD, C. K.
4137 Donchester St., W.
Montreal, Que.</p> <p>1911—MATHERS, WM.,
Montreal, Que.</p> <p>1919—MATHESON, H. W.
Canadian Electric Pro-
ducts Ltd., Shannigan
Falls, Que.</p> <p>1909—MONK, R. H.,
388 Grosvenor Ave.,
Westmount, Que.</p> <p>1903—MOONEY, G. A.,
324 St. Paul St.,
Montreal, Que.</p> <p>1915—MOONEY, F. M.,
32 St. Matthew St.,
Montreal, Que.</p> <p>1918—MOORE, A. B. J.,
12 Winchester Ave.,
Westmount, Que.</p> <p>1898—MORGAN, THOS. M.
370 Wood Ave.,
Westmount, Que.</p> <p>1916—MUNRO, A. J.,
41 Britannia St.,
Montreal, Que.</p> <p>1914—PASCOE, C. F.,
co. Canadian Steel
Foundries, Limited,
Longue Point, Montre</p> <p>1907—PINCOTT, E. S.
222 St. James St.,
Montreal, Que.</p> <p>1890—PLATTS, J. C., F.I.C.,
co. Armstrong-Whit-
worth of Canada, Ltd.,
Montreal, Que.</p> <p>1904—PRICHARD, N. B.,
40 Quebec Street,
Sherbrooke, Que.</p> | <p>ENTRY
YEAR
1916—REYNOLDS, C. W.
2021 St. Hubert St.,
Montreal, Que.</p> <p>1916—RILEY, LT. COL. J. J
604 McGill Bldg.,
Montreal, Que.</p> <p>1916—ROAST, H. J., F.C.S.
393 Guy St.,
Montreal, Que.</p> <p>1910—ROBERTSON, A. F.
co. National Chemical
Works, 27 St. Jean
Baptiste St., Montreal</p> <p>1918—ROWLEY, H. J.,
44 Rodney Street,
St. John, N.B.</p> <p>1905—RUTTAN, PROF. R. F
McGill University,
Montreal, Que.</p> <p>1910—RYAN, L. G.,
545 Notre Dame St. W.,
Montreal, Que.</p> <p>1907—SAXE, J. B.,
P.O. Box 1086,
Montreal, Que.</p> <p>1908—SELLEN, E.,
1285 Logan Street E.
Montreal, Que.</p> <p>1908—SNELL, PROF. J. F.
Macdonald College,
P.O., Que.</p> <p>1919—SPAFFORD, A. L.
4 Magog St., Sher-
brooke, Que.</p> <p>1903—SPENCER, A. G., MSc
co. Can. Inspection Co.,
603 Canadian Express
Bldg., Montreal, Que.</p> <p>1918—STEELE, G. F.,
co. Can. Export Paper
Co. Ltd., Sun Life Bldg.
Dominion Bldg.,
Montreal, Que.</p> <p>1919—St. GEORGE, H.
157 St. Dennis St.,
Montreal, Que.</p> <p>1914—STEFFANSON, G. B.,
P.O. Box 51,
Bathurst, N.B.</p> <p>1919—STEPHENSON, J. N.
Garden City Press,
Ste Anne de Bellevue,
Que.</p> <p>1909—STRACHAN, J. T.,
co. Canada Paper Co.,
Windsor Mills, Que.</p> <p>1916—WALKER, JAS.,
142 William St.,
Montreal, Que.</p> <p>1901—WALSH, L. O. P.,
Dominion Tar & Chemi-
cal Co., Sydney, C.B.</p> <p>1903—WALSH, PETER H.,
F.C.S., Box 569,
Magog, Que.</p> | <p>ENTRY
YEAR
1908—WARDLEWORTH, TH
32 St. Gabriel St.,
Montreal, Que.</p> <p>1914—WELLS, E. E.,
9 Dalhousie Street,
Montreal, Que.</p> <p>1919—WHITEHOUSE, G. W.
329 Lagauchetiere St.,
Montreal, Que.</p> <p>1916—WIEGAND, W. E.,
Canadian Consolidated
Rubber Co.,
Montreal, Que.</p> <p>1919—WOODHEAD, R.
120 St. James St.,
Montreal, Que.</p> <p>WINNIPEG DISTRICT
PRAIRIE PROVINCES
1918—BIRCHARD, DR. F. T.
co. Dominion Grain Lab
Winnipeg, Man.
1910—BLACKIE, A.,
223 James Street,
Winnipeg, Man.
1916—CAROTHERS, A.,
164 Roseberry St.,
St. James,
Winnipeg, Man.
1910—COOPER, L. H.,
co. Royal Crown
Co., Calgary, Alta
1916—FORSTER, E. L.
M.A.,
Postal Station B.,
Winnipeg, Man.
1918—KIPP, THOS., Jr.,
132 Montrose St.,
Winnipeg, Man.
1907—LEHMAN, A., Ph.D.
University of Alberta,
Strathcona, Alta.
1918—MacLAURIN, DR. R.D
University of Saskche-
wan, Saskatoon, Sask.
1906—MORROW, J. M.,
71 Tache Ave., Norwood
Grove, St. Boniface, Ma
1897—PARKER, PROF., M.A.
University of Manitoba,
Winnipeg, Man.</p> <p>CANADIAN PACIFIC
SECTION
1918—ARMSTRONG, N. T.,
1962 6th Ave. East,
Vancouver, B.C.
1918—BARWICK, W. S.
519 6th Ave. West,
Vancouver, B.C.</p> |
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- 1918—BERKELEY, C. J.,
2412 Alder St.,
Vancouver, B.C.
- 1913—BOYD, ROBERT,
co. British Columbia
Sugar Refining Co.,
Vancouver, B.C.
- 1918—BURROWES, G.,
Comox, B.C.
- 1918—CALVIN, R. F.,
3264 7th Ave. West,
Vancouver, B.C.
- 1918—CAMPBELL, D.,
510 Hastings St. West,
Vancouver, B.C.
- 1896—CARMICHAEL, HERBERT
Bureau of Mines,
Victoria, B.C.
- 1917—CLARK, DR. R. H.,
University of B.C.,
Vancouver, B.C.
- 1918—CUNCLIFFE, B. A.,
365 Water Street,
Vancouver, B.C.
- 1918—DAVISON, I. R.,
402 Pender St. W.,
Vancouver, B. C.
- 1916—DAWSON, J. A.,
326 Howe St.,
Vancouver, B.C.
- 1917—ELDRIDGE, G. S.,
567 Hornby St.,
Vancouver, B.C.
- 1918—ELLIOTT, PROF. H. P
University of B.C.,
Vancouver, B.C.
- 1918—FERGUSON, WM. G.,
Box 853,
Trail, B.C.
- 1899—FINGLAND, J. J.,
Kaslo, B.C.
- 1900—FRENCH, THOS.,
806 Stanley St.,
Nelson, B.C.
- 1914—GARDINER, H. J.,
"Fir Royd" 242 24th St
West, North Vancouver
British Columbia.
- 1917—GIOVELLINA, E. C.,
de, B.A.,
1348 Robson Street,
Vancouver, B.C.
- 1916—HAMILTON, E. H.,
co. Cons. Mining &
Smelting Co.,
Trail, B.C.
- 1918—HILL, W. H.,
326 Harvey Street,
Vancouver, B.C.
- 1917—HOCKIN, D.,
796 Beatty Street,
Vancouver, B.C.
- 1918—KENNEDY, JOS.,
160 Horner Street,
Vancouver, B.C.
- 1918—KEILLOR, M.,
1230 Burnaby Street,
Vancouver, B.C.
- 1919—MACKENZIE, Dr. R.
1650 Harwood St.,
Vancouver, B.C.
- 1918—McINTOSH, Prof. D.
University of B.C.
Vancouver, B.C.
- 1918—MALKIN, W. H.,
57 Water Street,
Vancouver, B.C.
- 1918—MAUDE, A. H.,
co. Can. Explosives Ltd
Nanaimo, B.C.
- 1902—MOORE, FRED,
Can. Explosives, Ltd.,
Victoria, B.C.
- 1918—REID, S. D.,
P.O. Box 1092,
Vancouver, B.C.
- 1919—STEWART, F. R.
1503 Angus Ave,
Vancouver, B.C.
- 1918—TEPOORTEN, J. A.,
308 Water Street,
Vancouver, B.C.
- 1917—VANCE, J. F.,
947 Richard Street,
Vancouver, B.C.

PREVIOUS PUBLICATIONS.

The Economics of Power Production.

Some Canadian Industrial Problems.

Foods.

The Chemical Industries of Canada.

Industrial Alcohol.

Some Applications of Chemistry to Industrial Processes.

The Chemists of Canada.

NOTE—Copies may be obtained upon application to the Secretary

